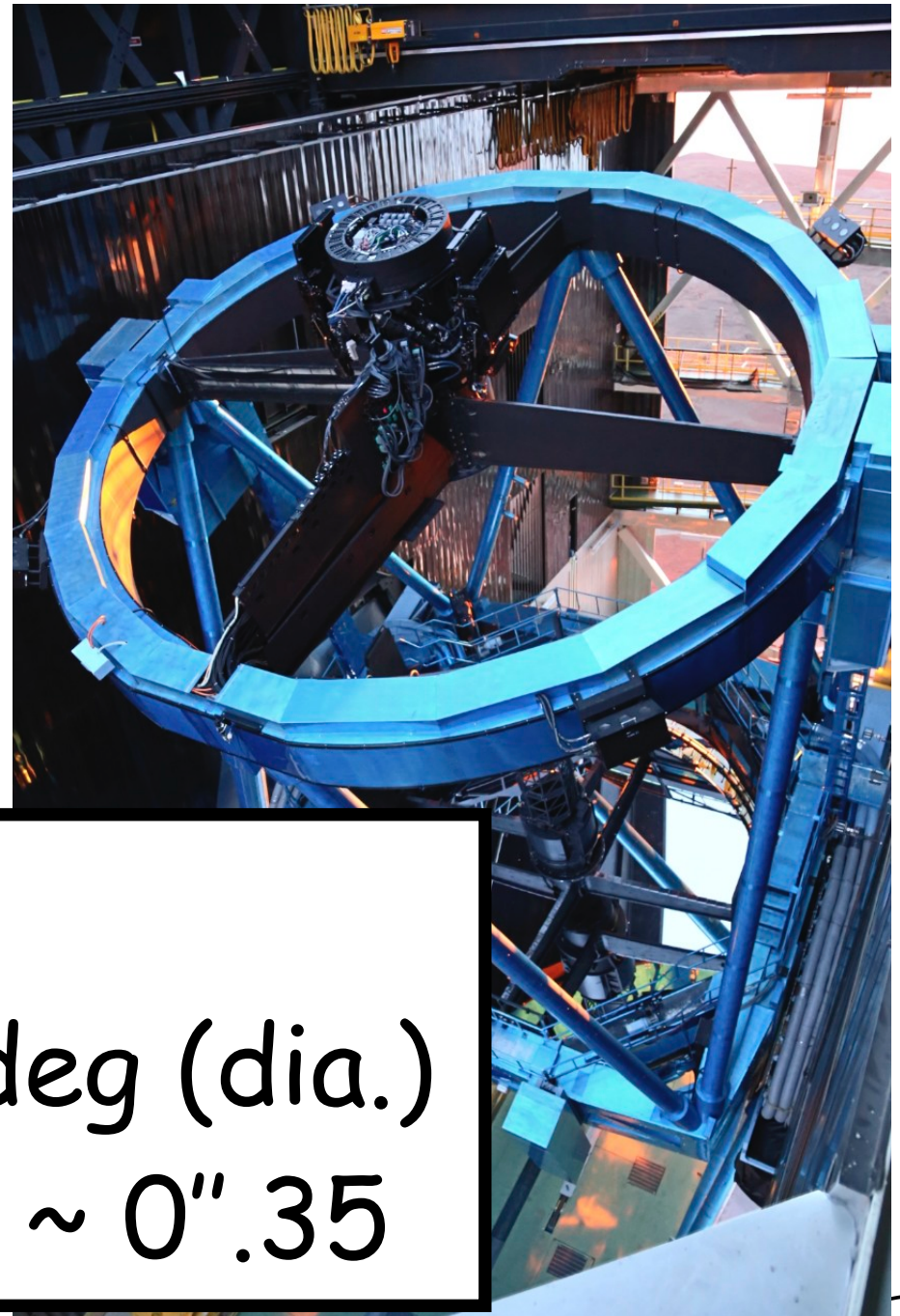
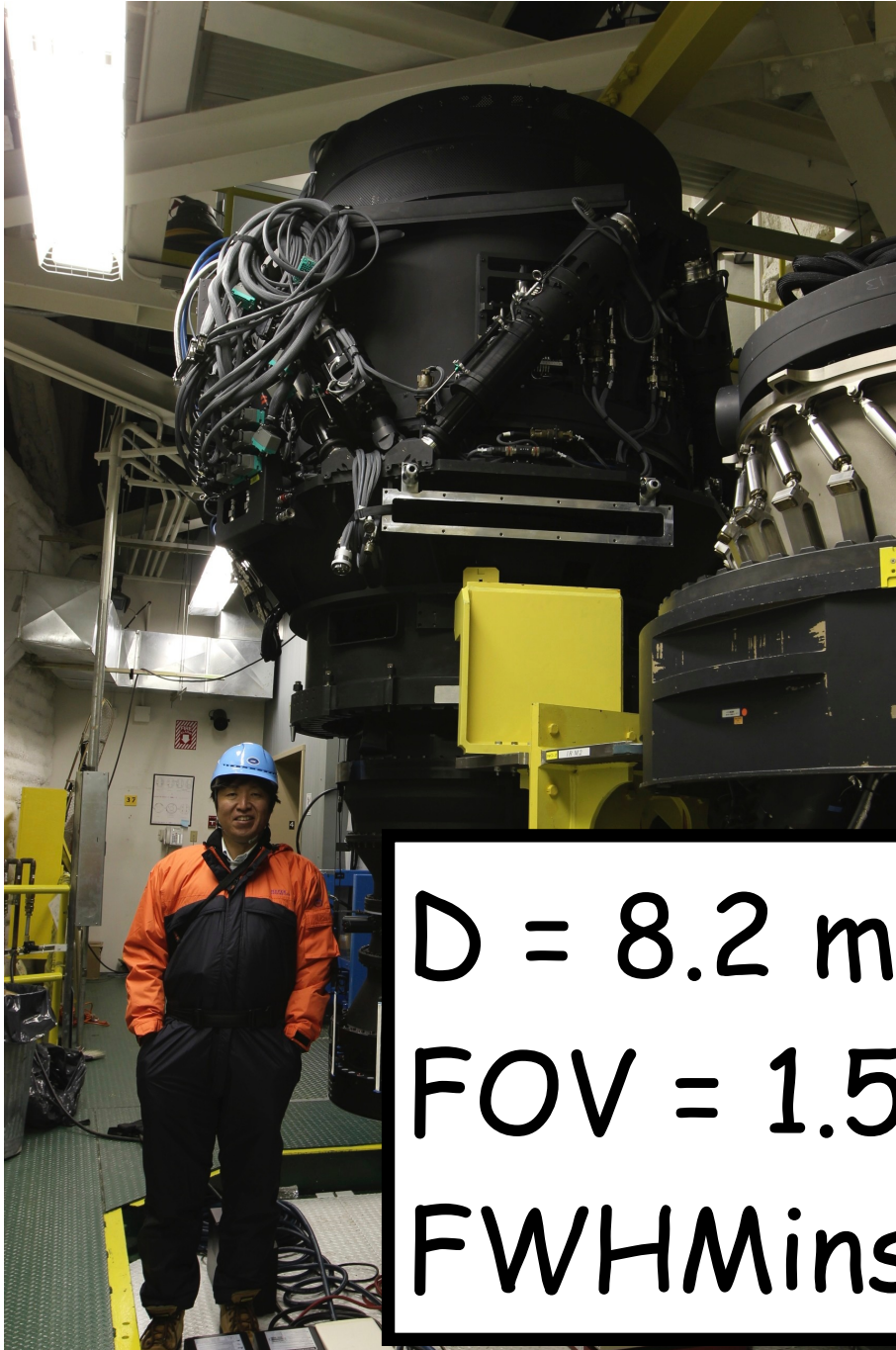


# Hyper Suprime-Cam Satoshi Miyazaki NAOJ







$D = 8.2 \text{ m}$

$\text{FOV} = 1.5 \text{ deg (dia.)}$

$\text{FWHM}_{\text{inst}} \sim 0''.35$



# Comparison

|                | Suprime-Cam | HSC     |
|----------------|-------------|---------|
| Field of View  | 0.5 deg     | 1.5 deg |
| No. of CCDs    | 10          | 116     |
| Inst. Img Qlty | 0".33       | 0".35   |
| First Light    | 1999        | 2012    |

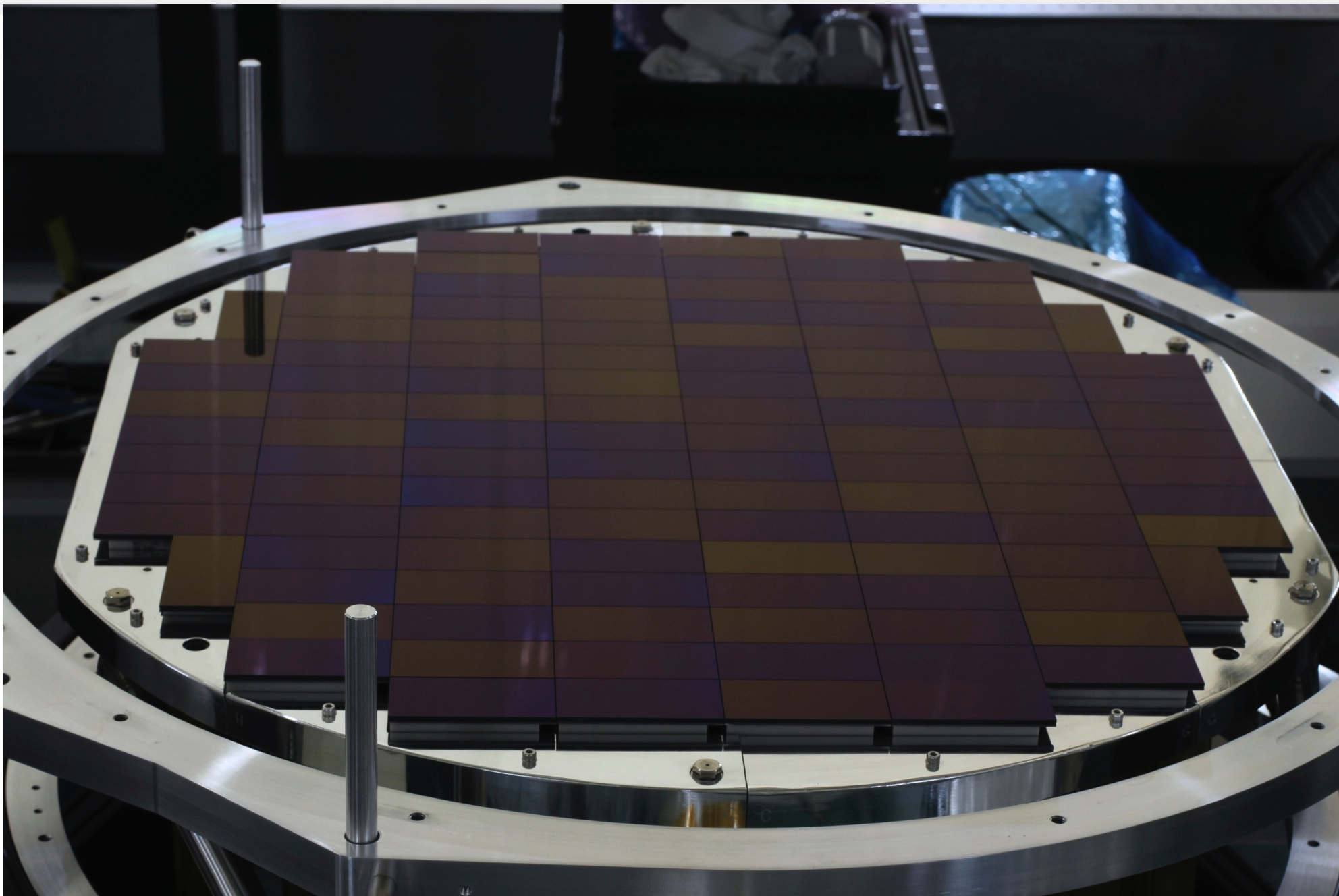


# Comparison

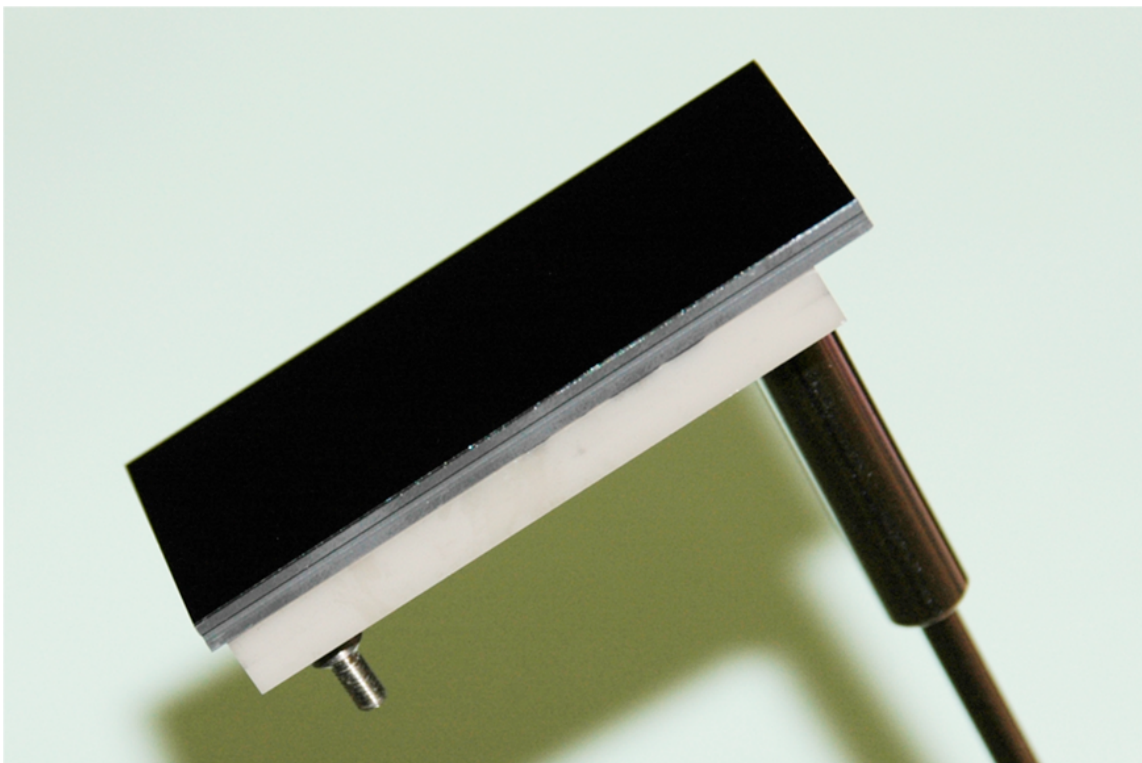
|                | HSC   | Pan-STARRS | DES    | LSST    |
|----------------|-------|------------|--------|---------|
| Aperture [m]   | 8.2   | 1.8        | 4.0    | 6.5(eq) |
| Survey Speed   | 91    | 13.4       | 37     | 329     |
| Inst. Img Qlty | 0".35 | ~ 0".6     | ~ 0".6 | ?       |
| First Light    | 2012  | 2009       | 2012   | (2019)  |
| Lead Country   | JP    | US         | US     | US      |



# 116 Mosaic CCD



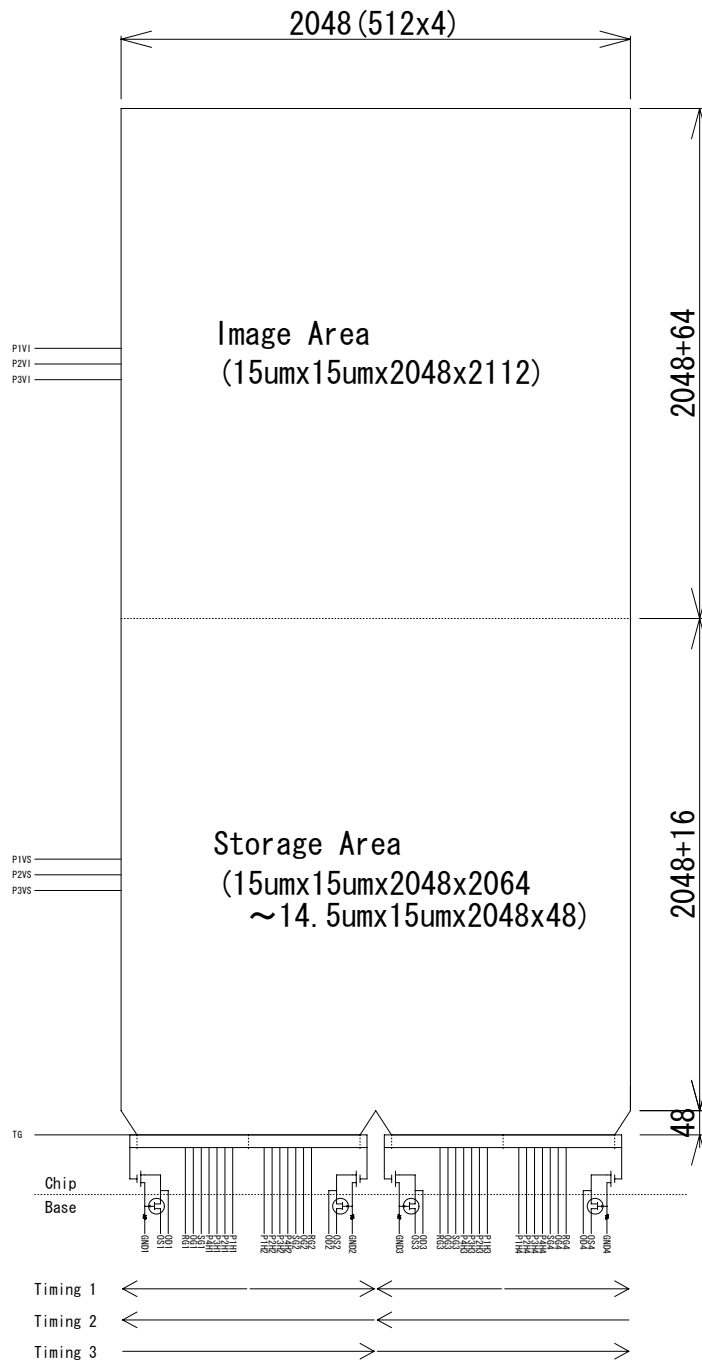
## Collaboration with Hamamatsu since 1994



- 2k4k 15 $\mu$ m
- Fully depleted CCD
- High resistivity Si
  - > 10 k $\Omega$  (n type)
- 200  $\mu$ m thick
  - (can be ~ 300  $\mu$ m)

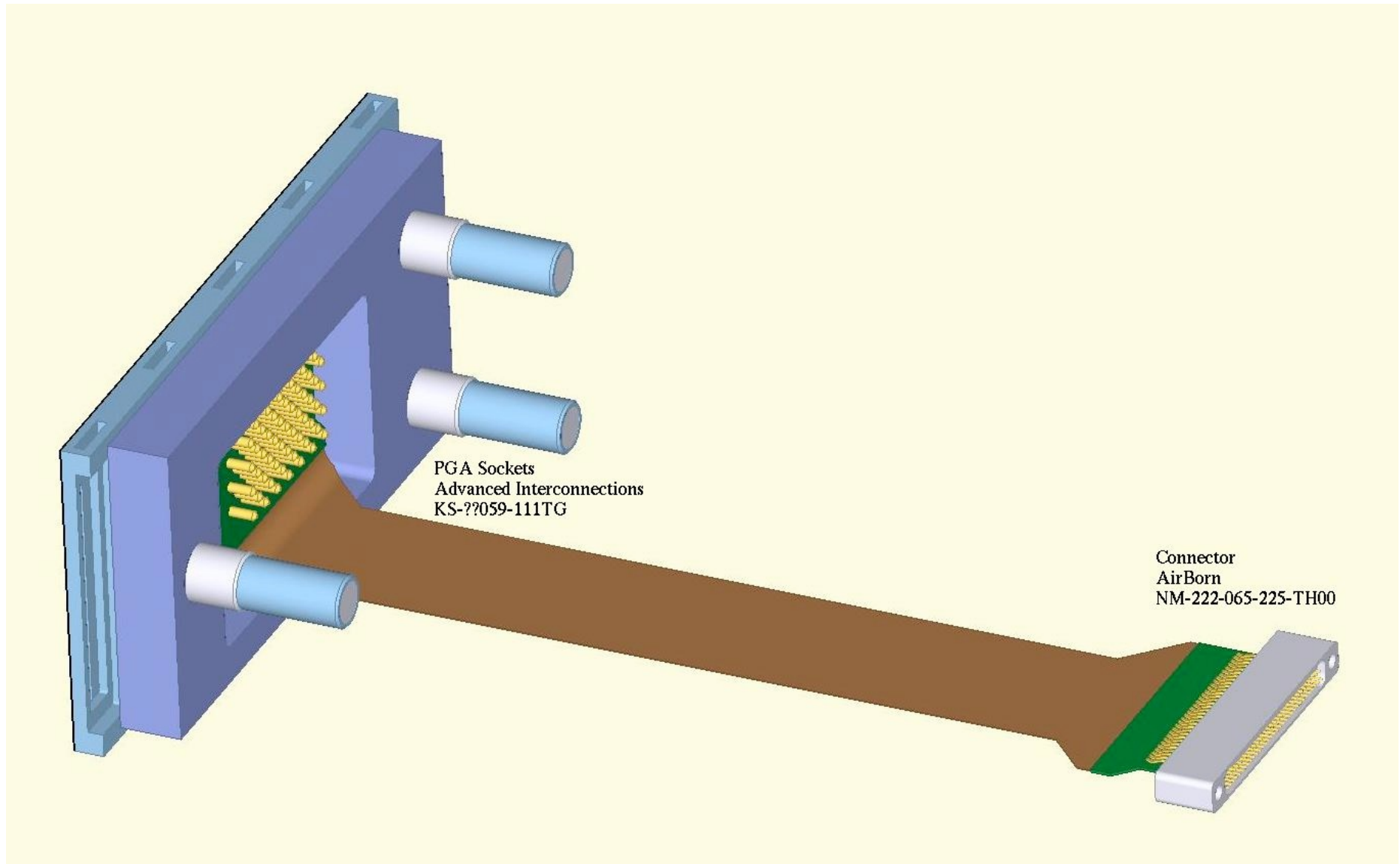


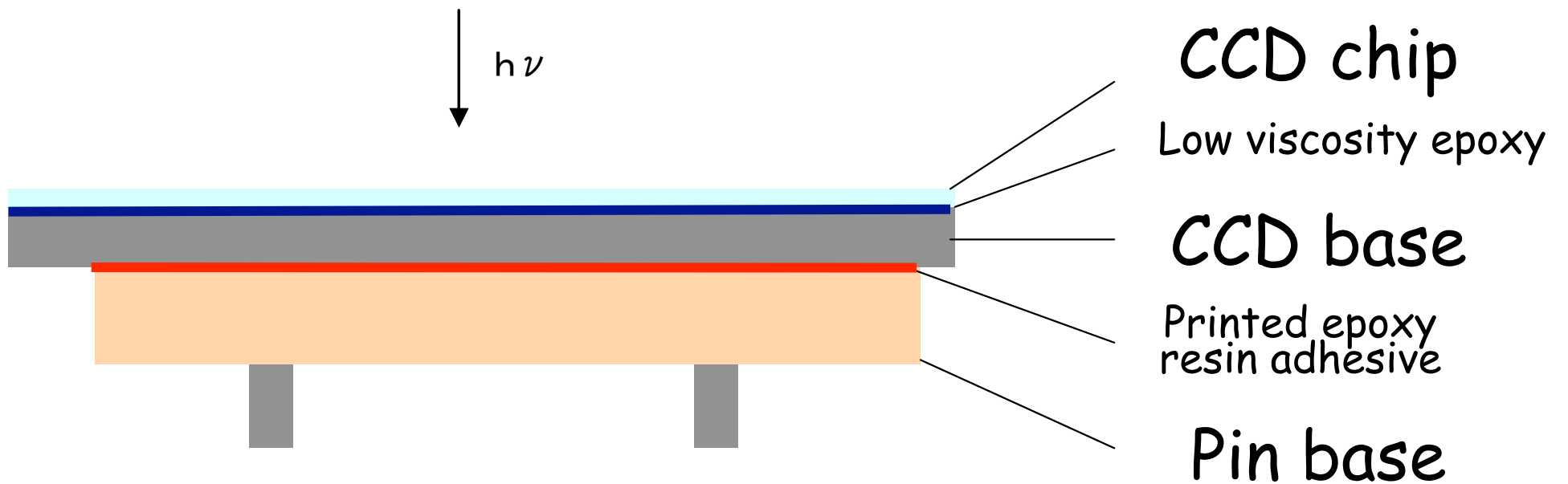
# HPK Fully Depleted CCD



|                        |   |
|------------------------|---|
| CCD Structure          | Full Frame Transfer                                     |
| Si Thickness           | 200 $\mu\text{m}$ (Can be 100 ~ 300 $\mu\text{m}$ )     |
| Vertical clock phase   | 3 phases  |
| Horizontal clock phase | 2 phases or 4 phases                                    |
| Output Amplifiers      | 4 one stage MOSFET on chip and one J-FET on the package |
| Package Material       | Aluminum Nitride  |

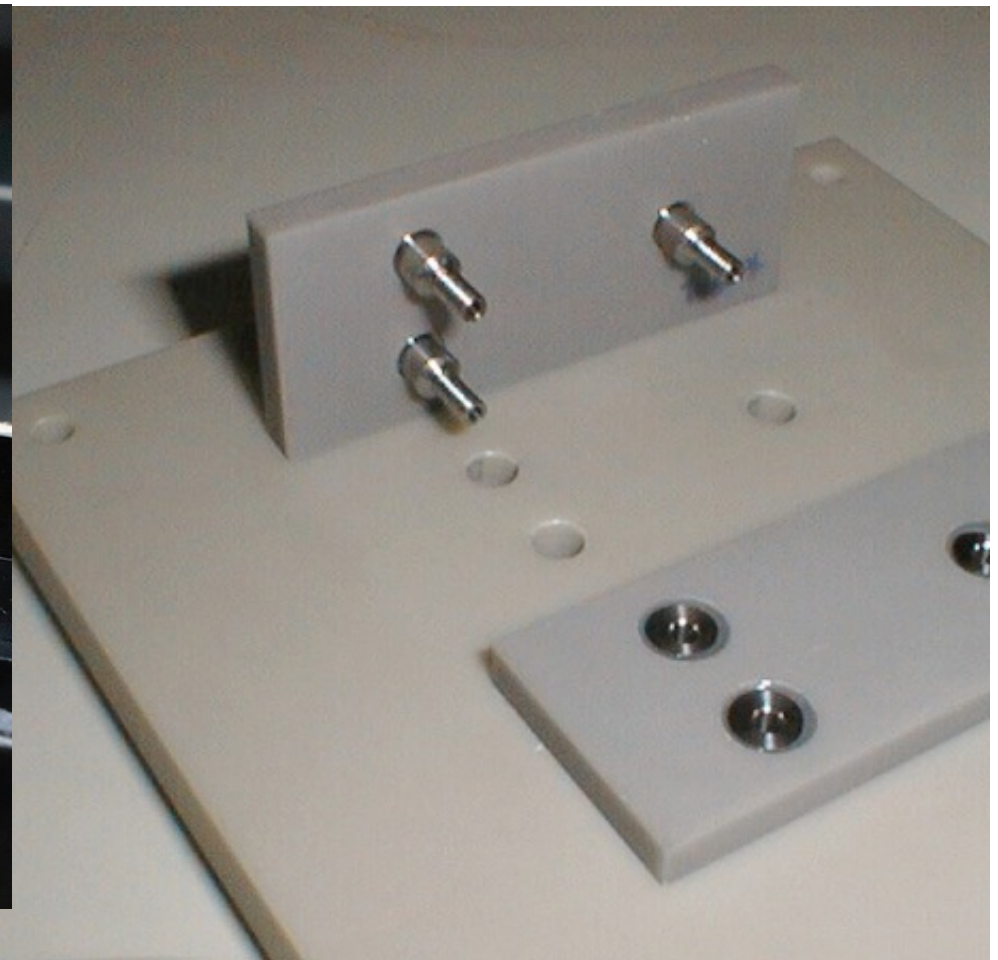
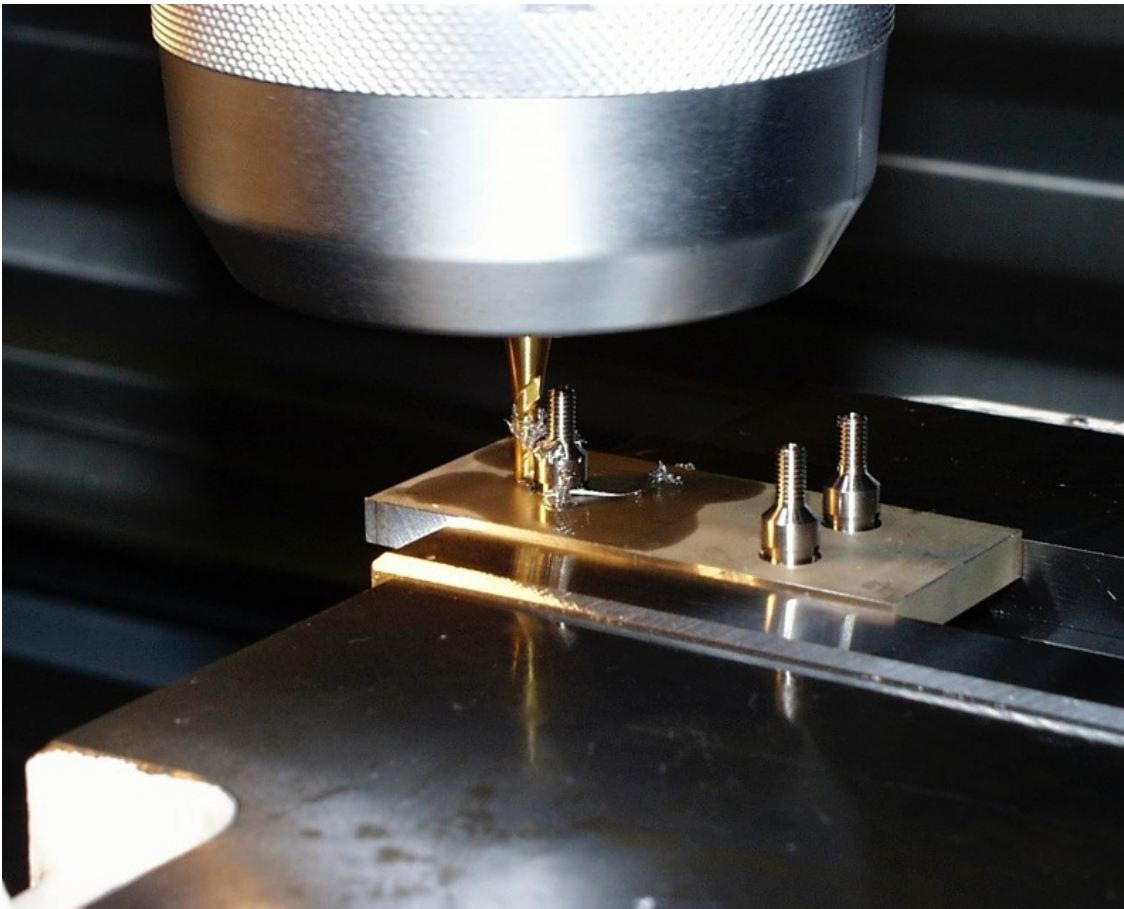






# Pin Base

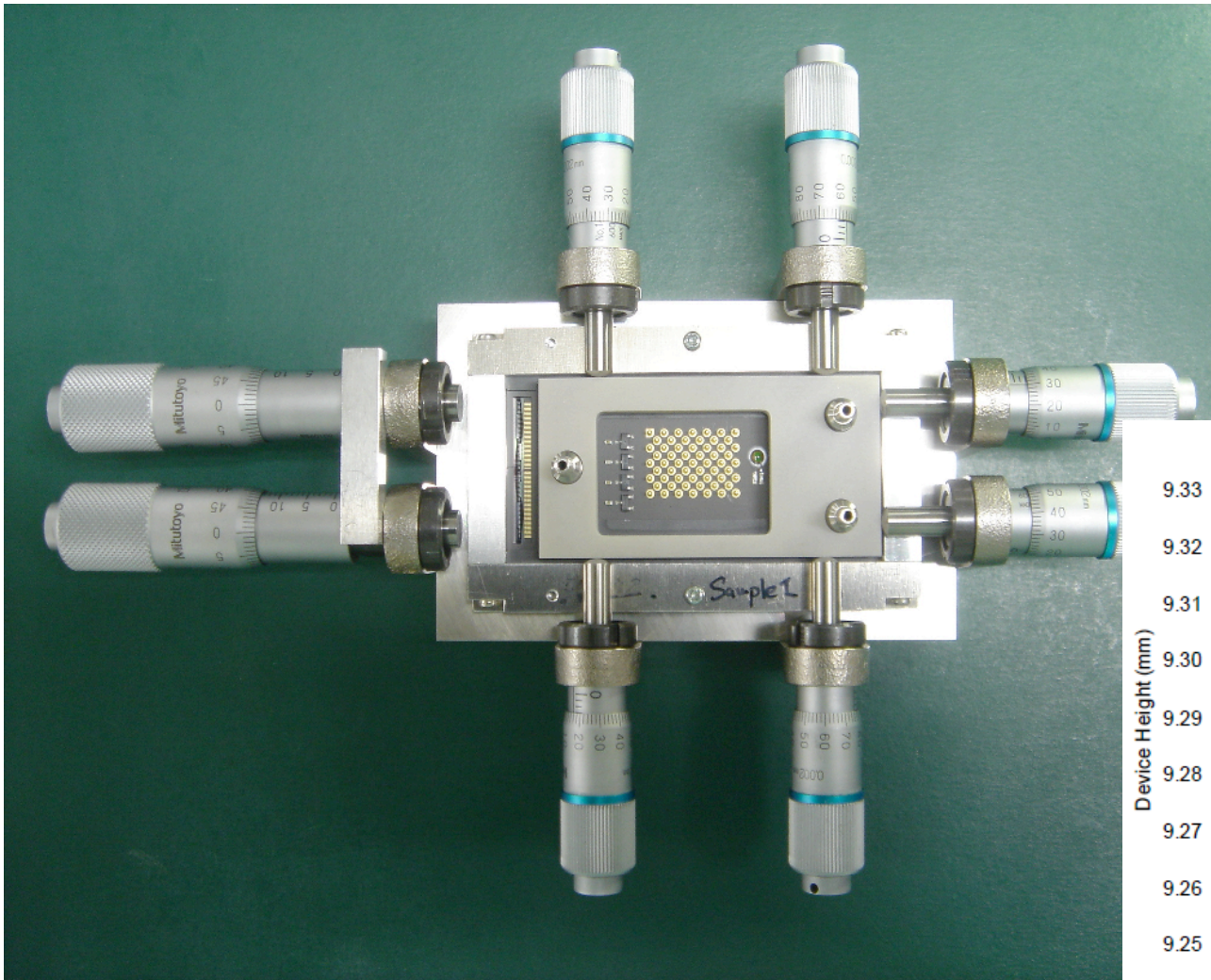
- AlN with Ti alignment pins



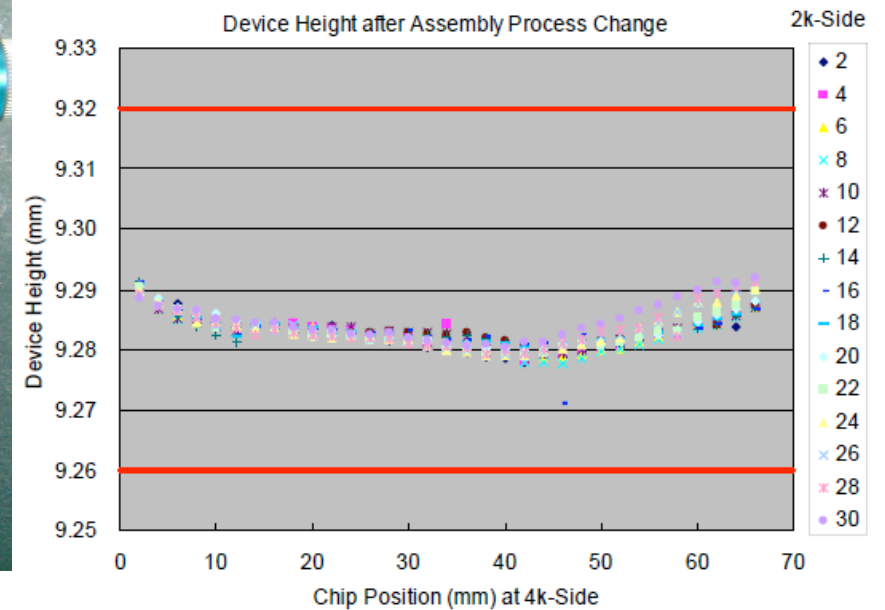
Fit tolerance  $\sim 40 \mu\text{m}$



# Package Structure



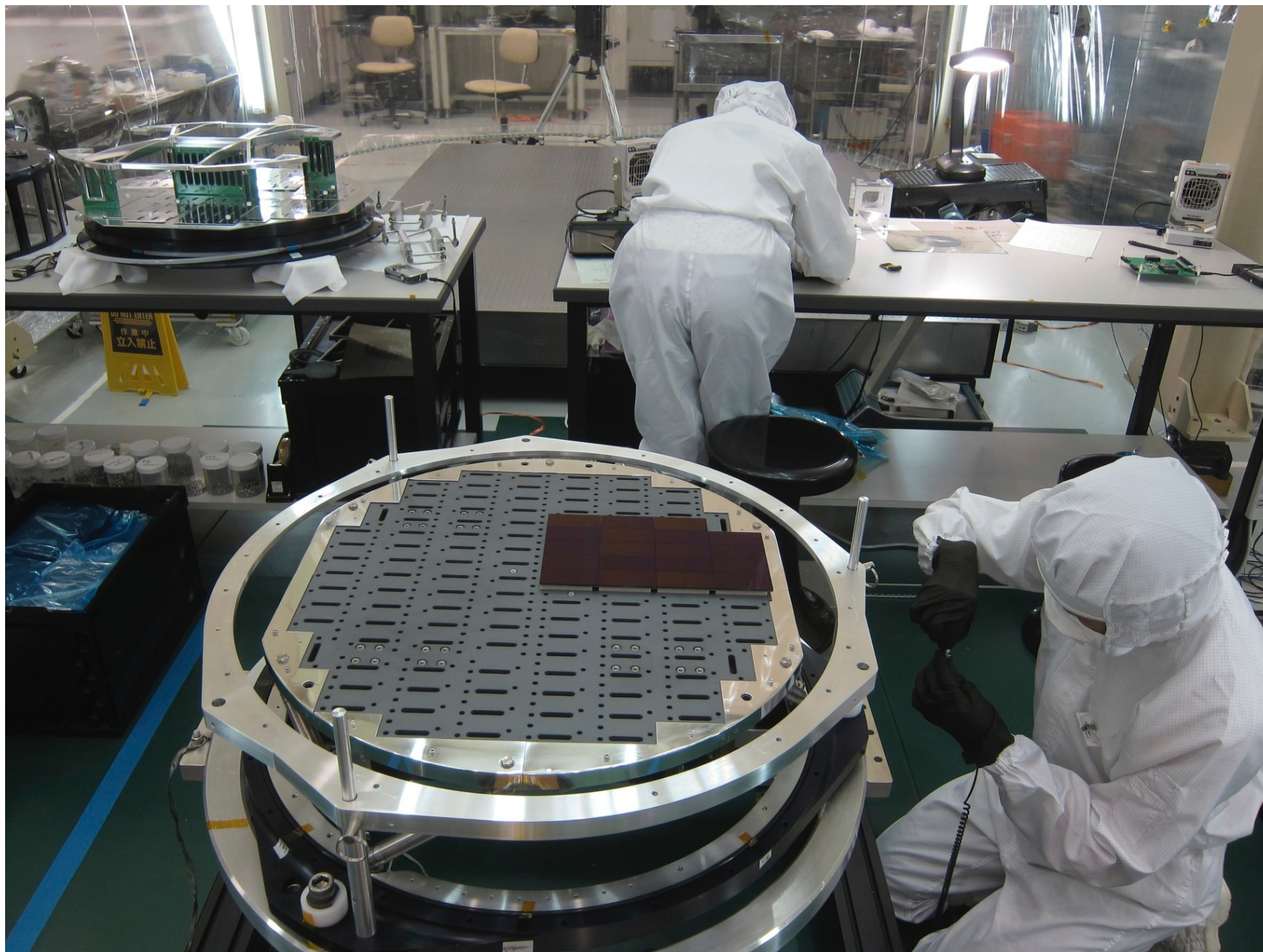
10um  
flatness  
achieved



Pixel  $\leftrightarrow$  Pin alignment  $\sim 60 \mu\text{m}$



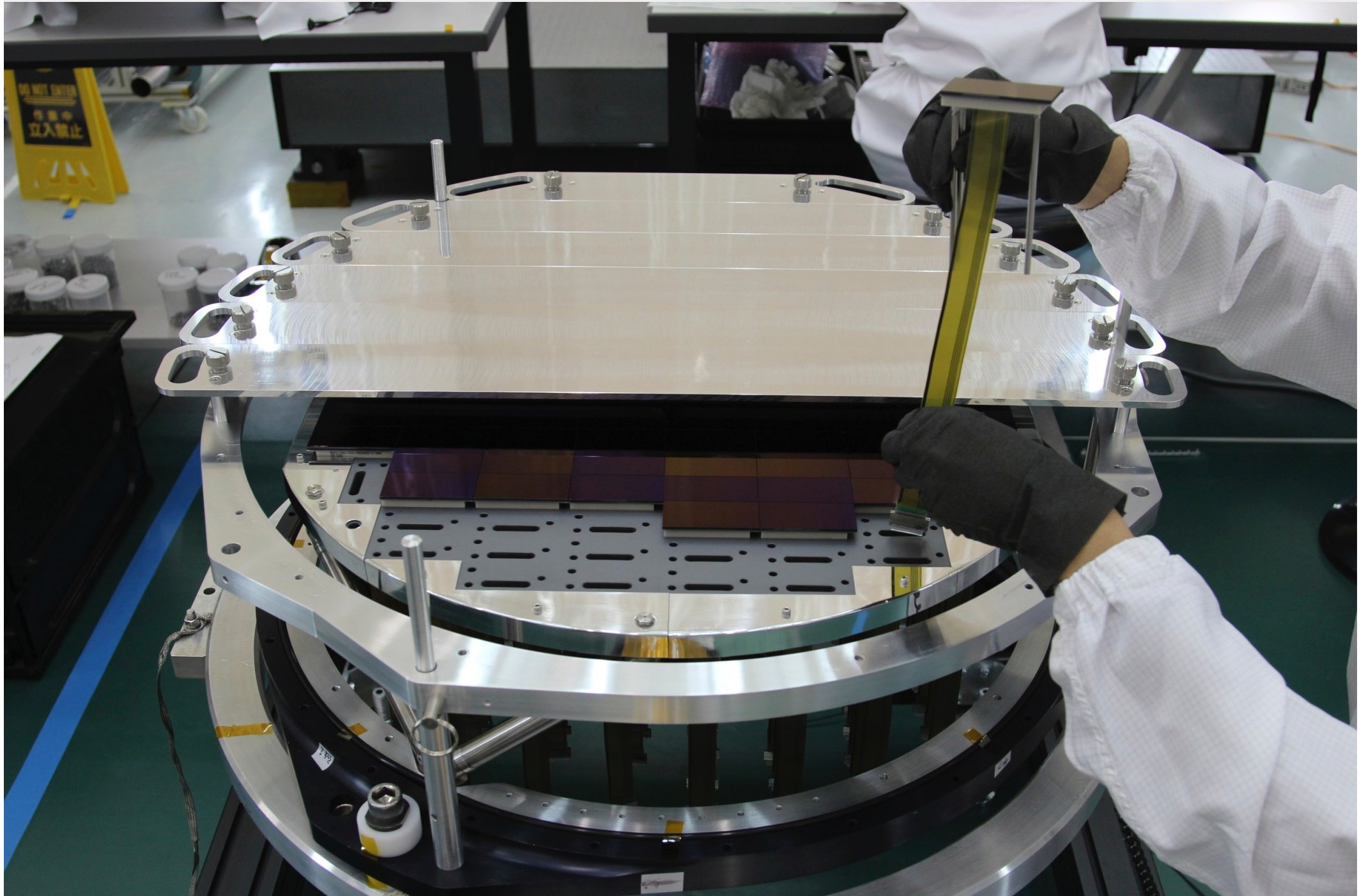
# Mounting CCDs







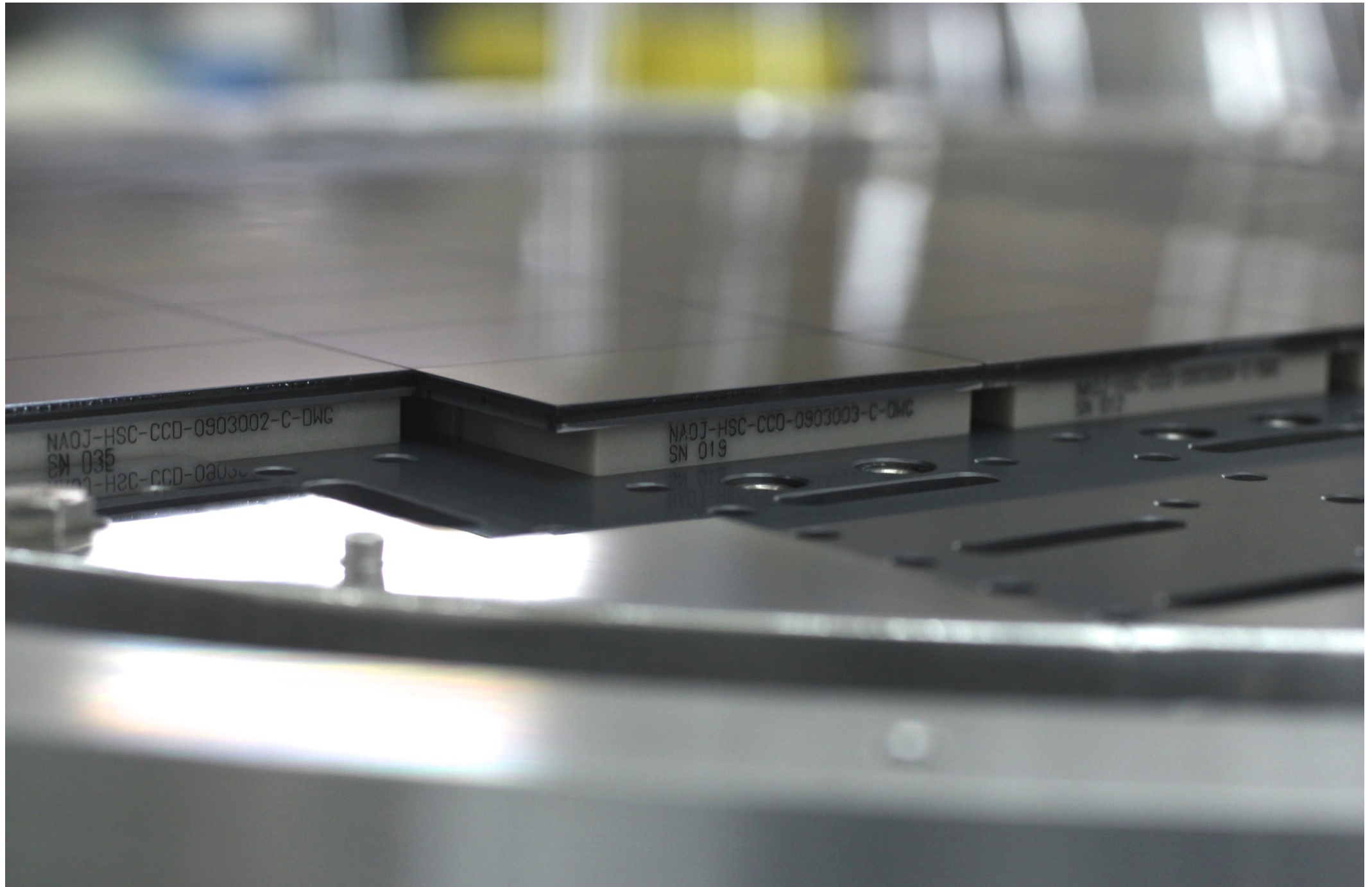
# Mounting CCDs



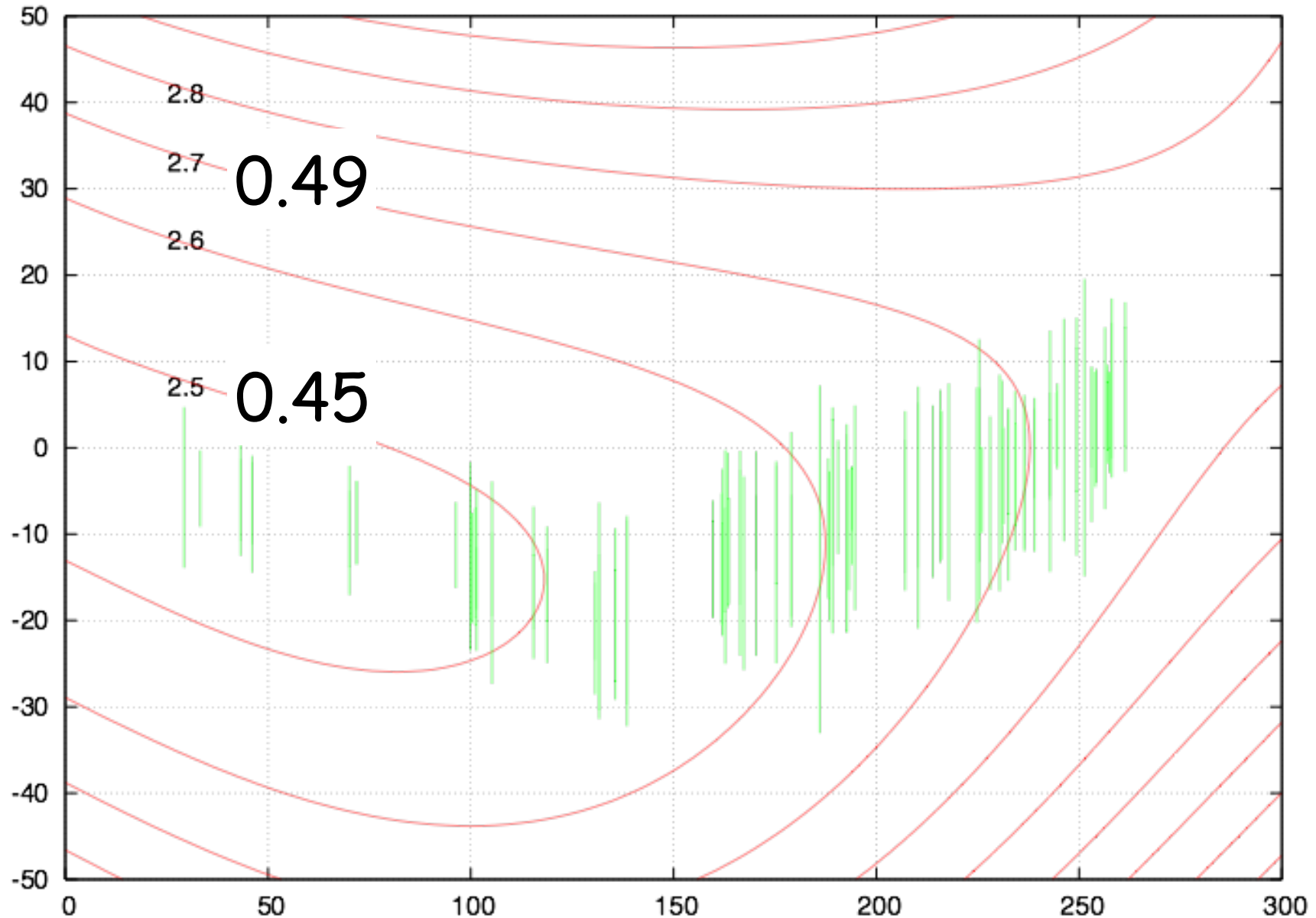




# Mounting CCDs



# Flatness of the Focal Plane

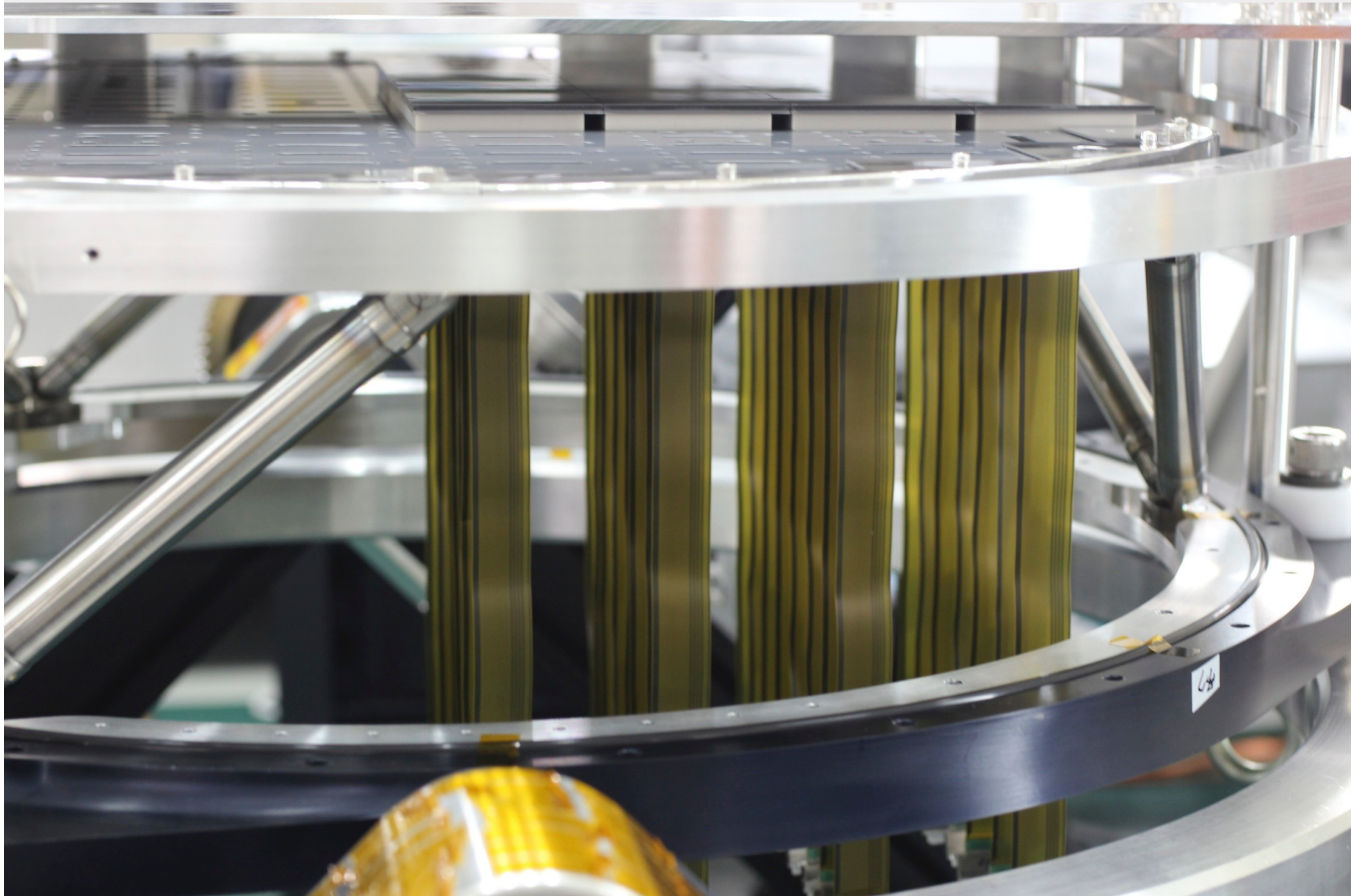


Red contour: Delivered PSF under 0.4 arcsec seeing



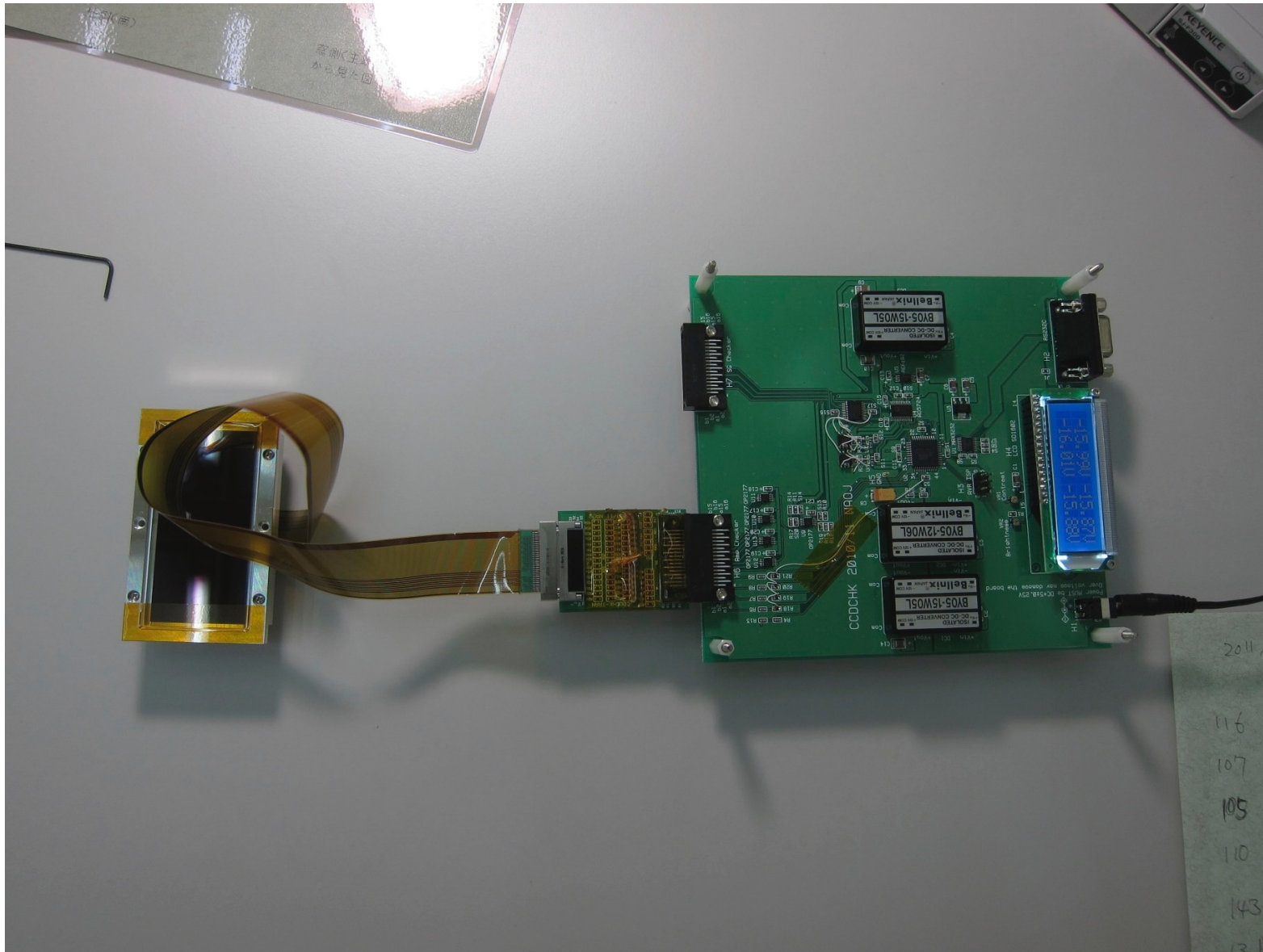


# Mounting CCDs





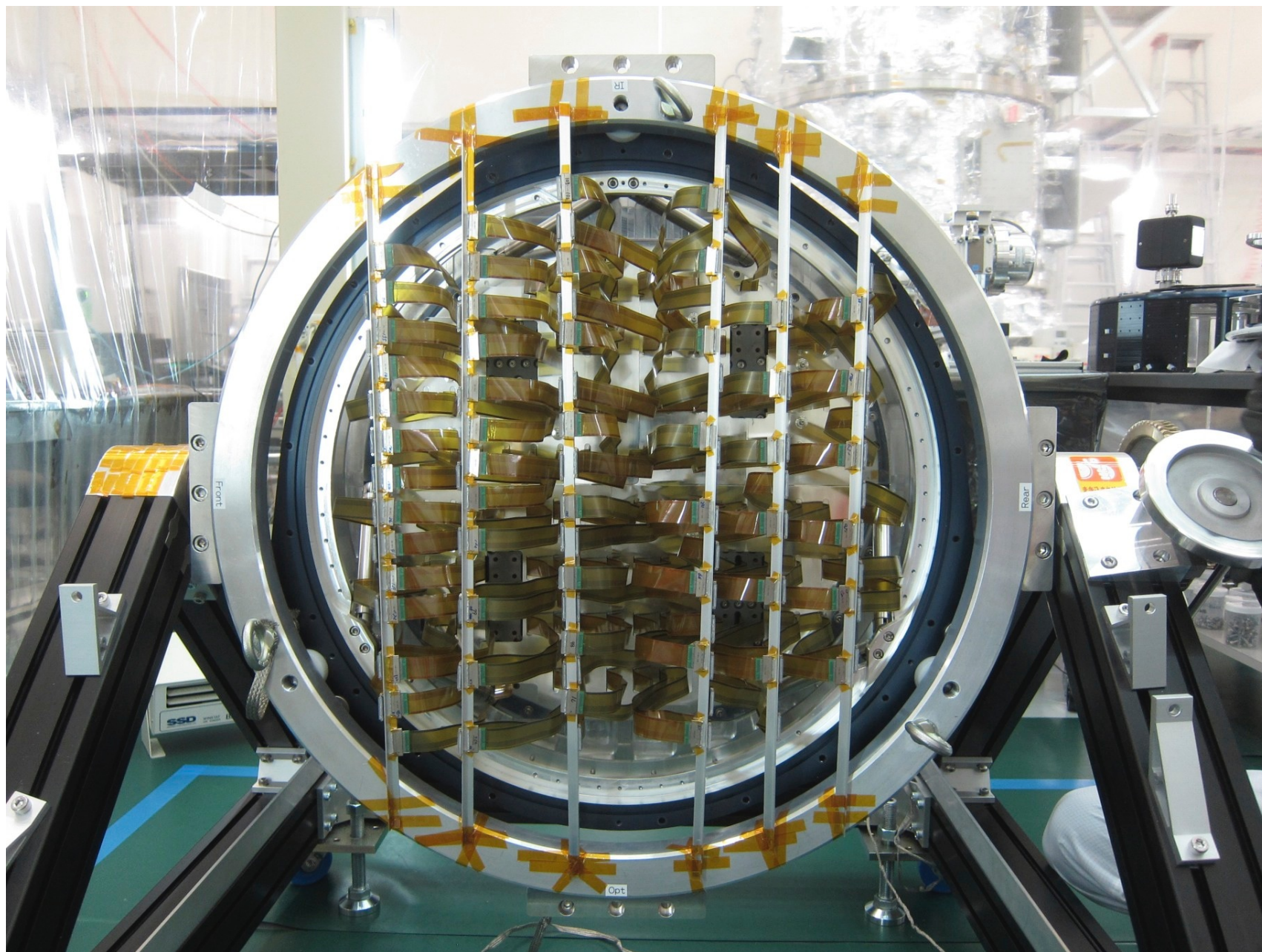
# CCD Checker



Final Check: Amplifier, SG

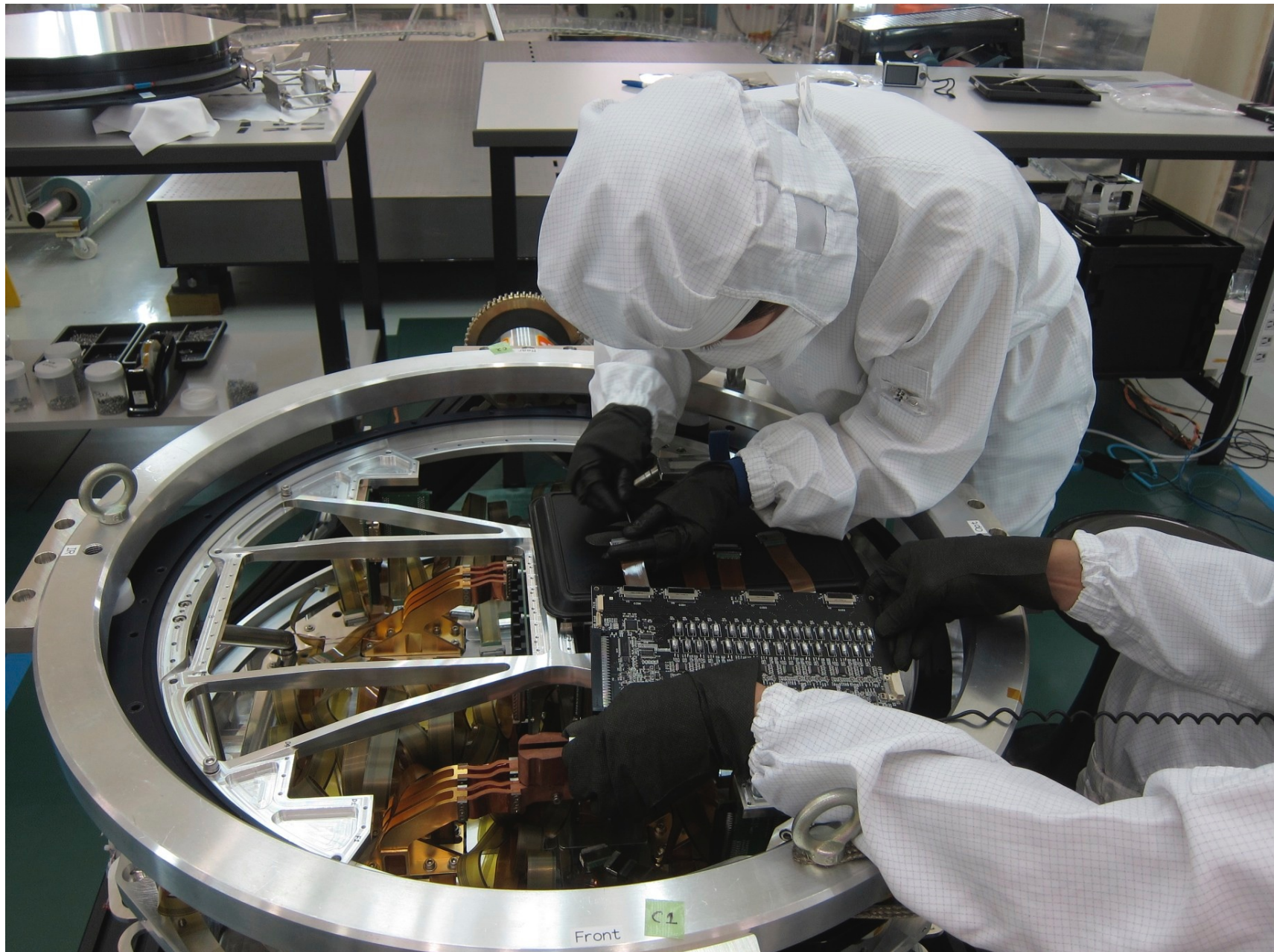


# Backside ...



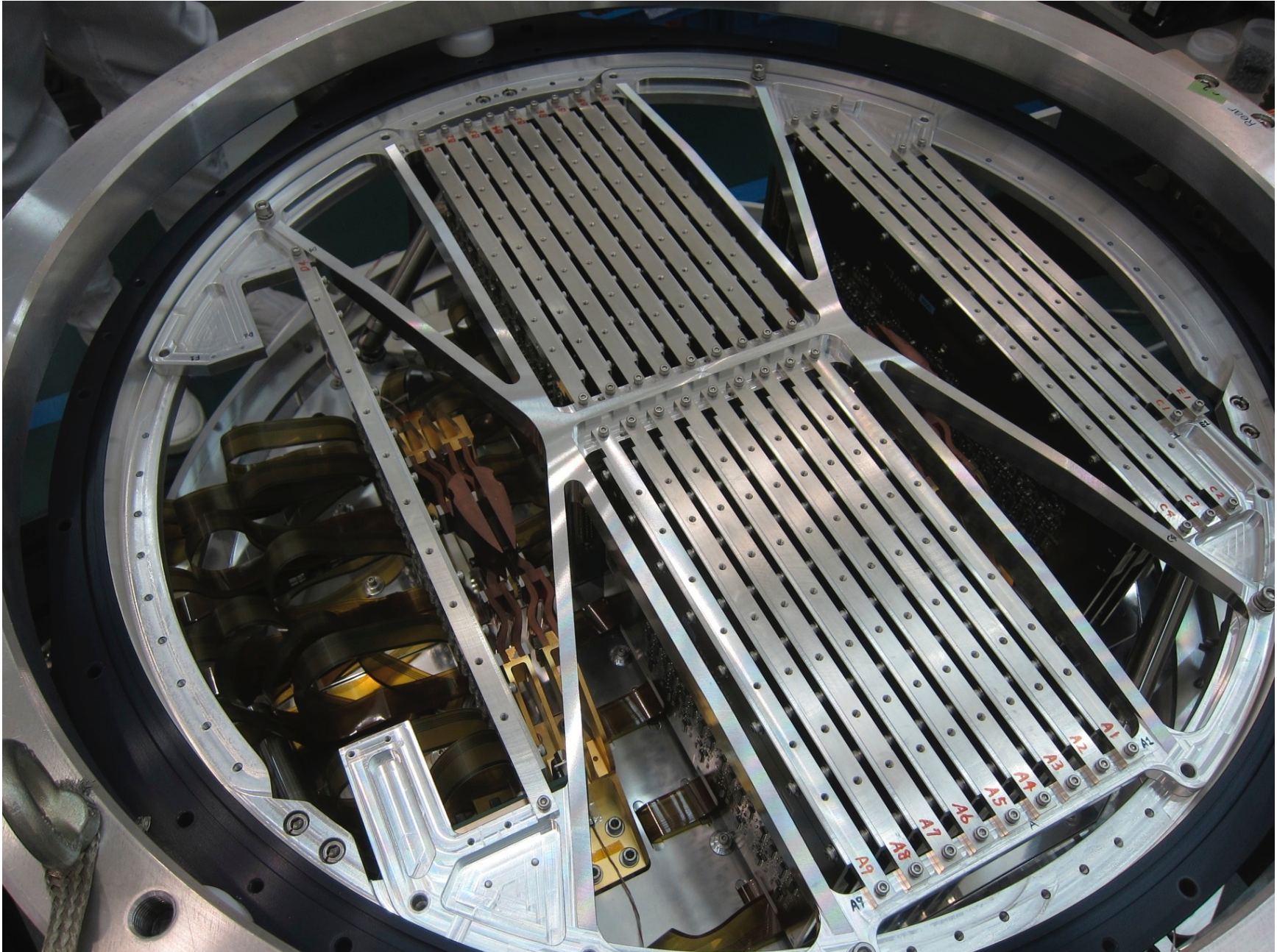


# Electronics Connection



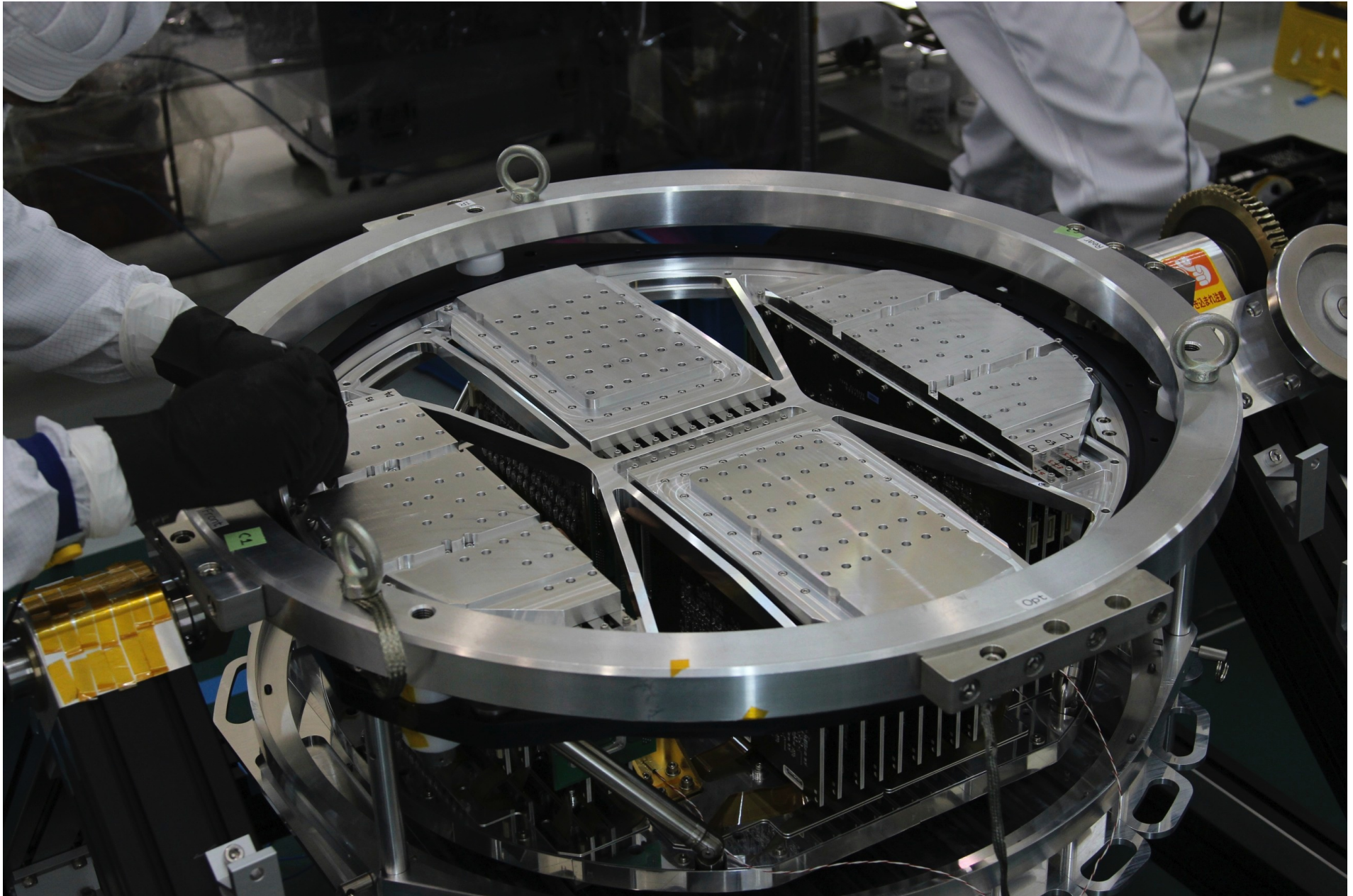


# Electronics Arrays



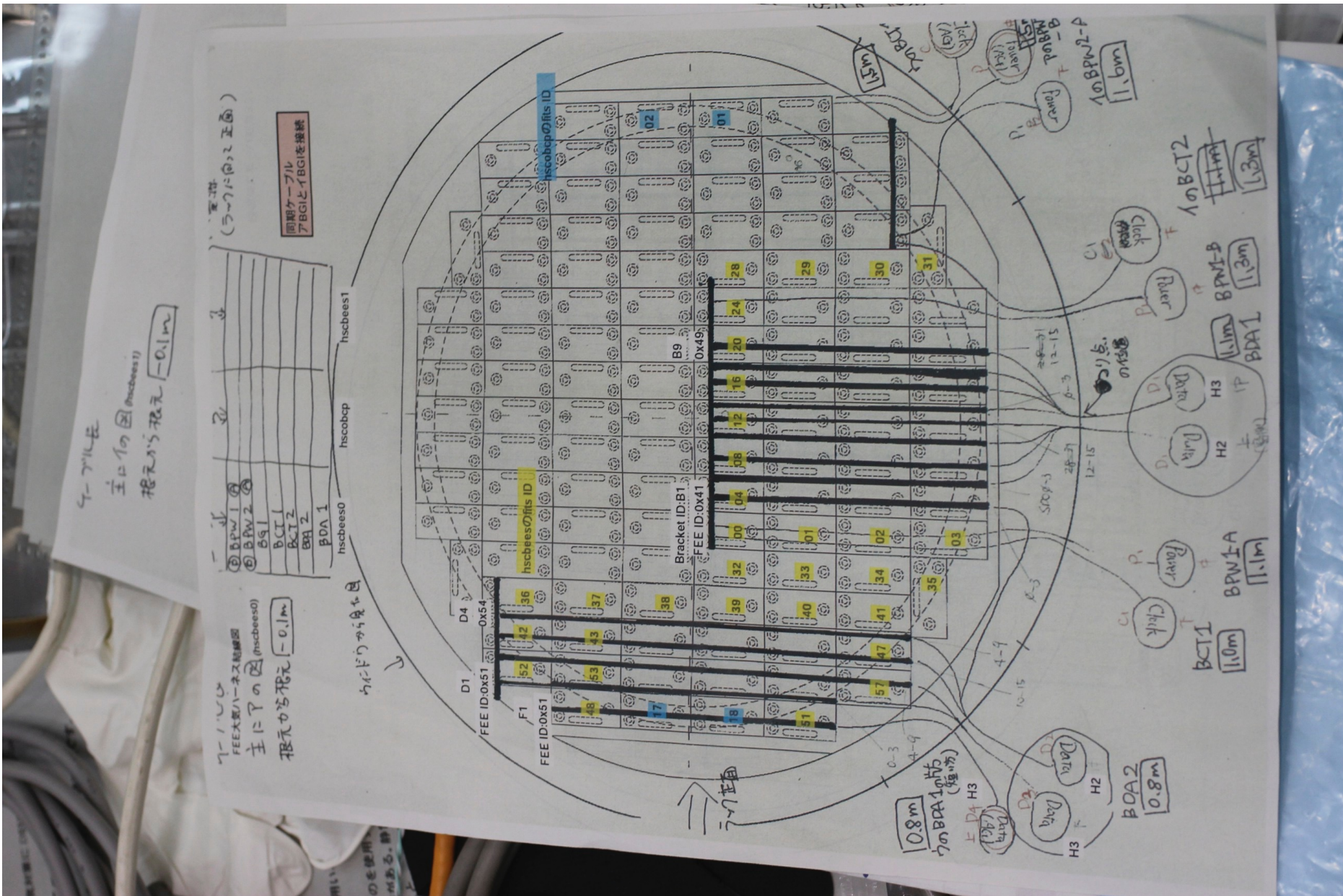


# Electronics Cooling





# Official Drawing ...





# CCD Clocking

AD5361

ADG333

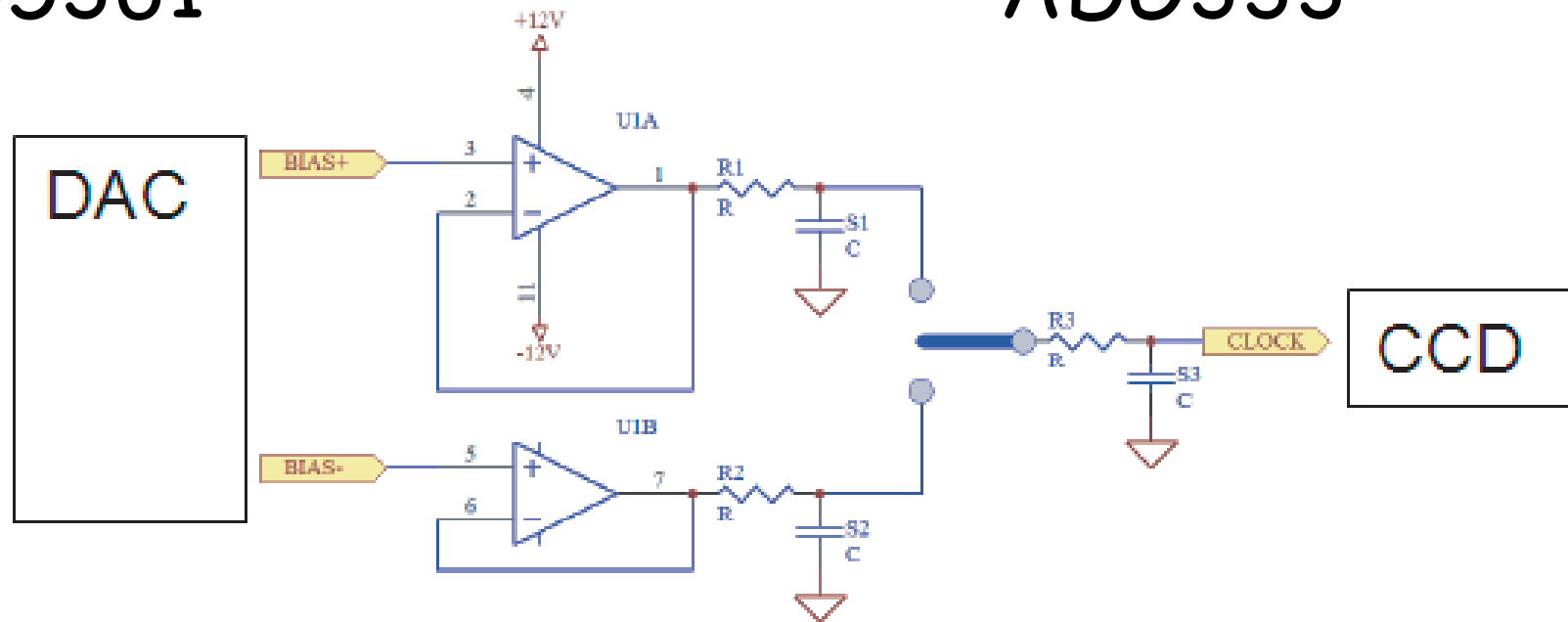


Figure 6.27: Clock Driver Circuit

# CCD Read Out

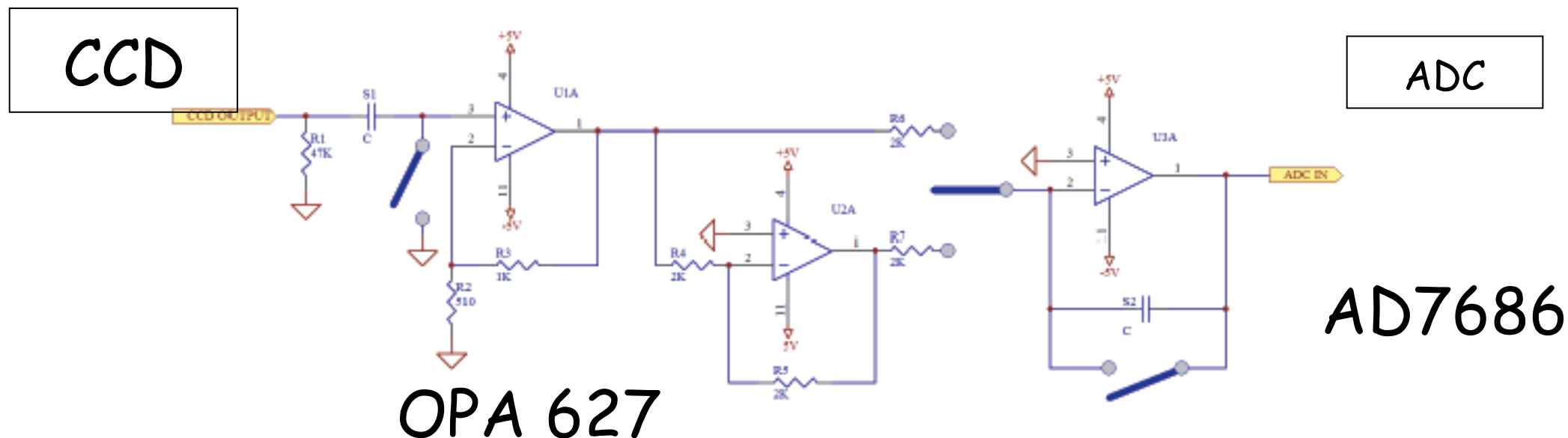


Figure 1.4: Pre-amplifier and CDS circuit

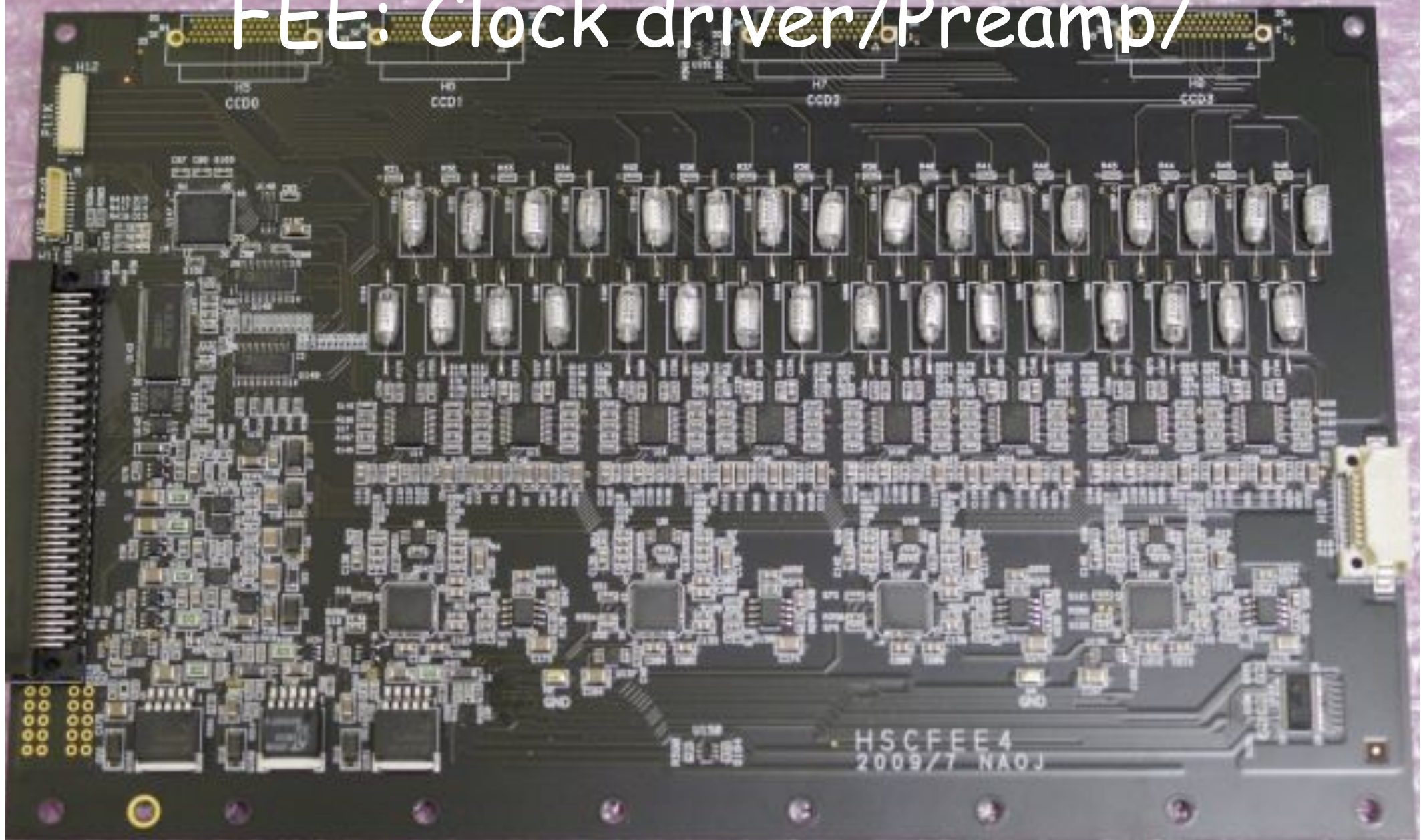
AC-couple

Single Non-inverting Amp

Integration Type  
CDS

~ 150 kpix/sec =  
15 sec readout

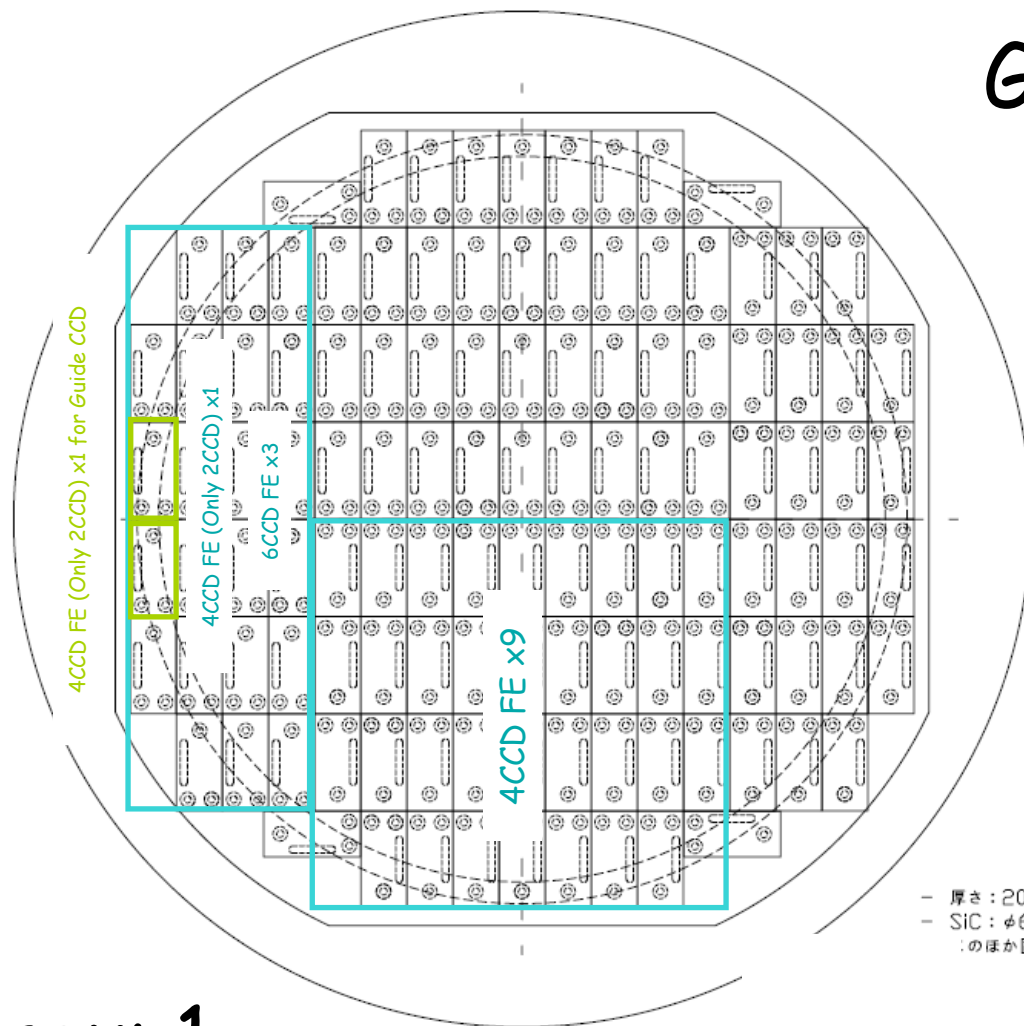
# FEE: Clock driver/Preamp/



AI core



# FEE arrangement in Dewar

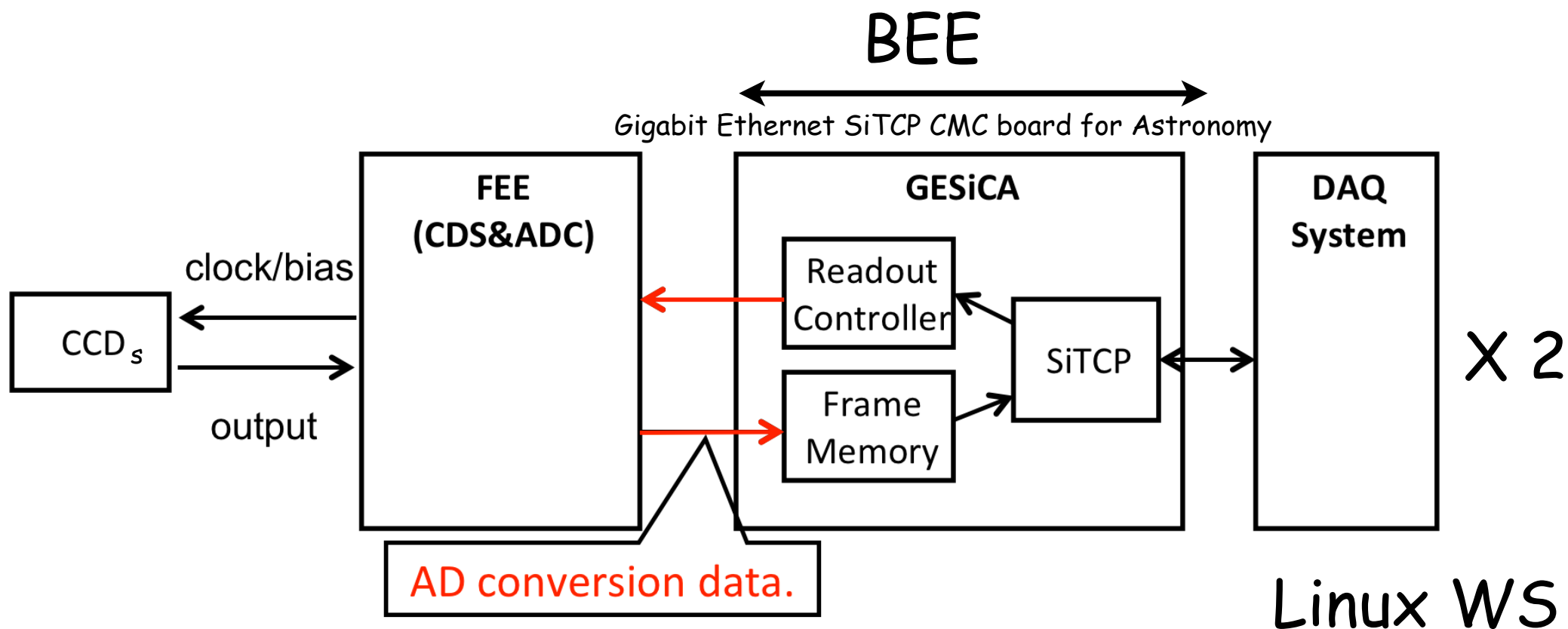


Group2

Group1. 4CCD FE board x1  
(Used only 2CCD)

CCD in two groups  
synchronous clocking

# Backend Electronics (BEE)



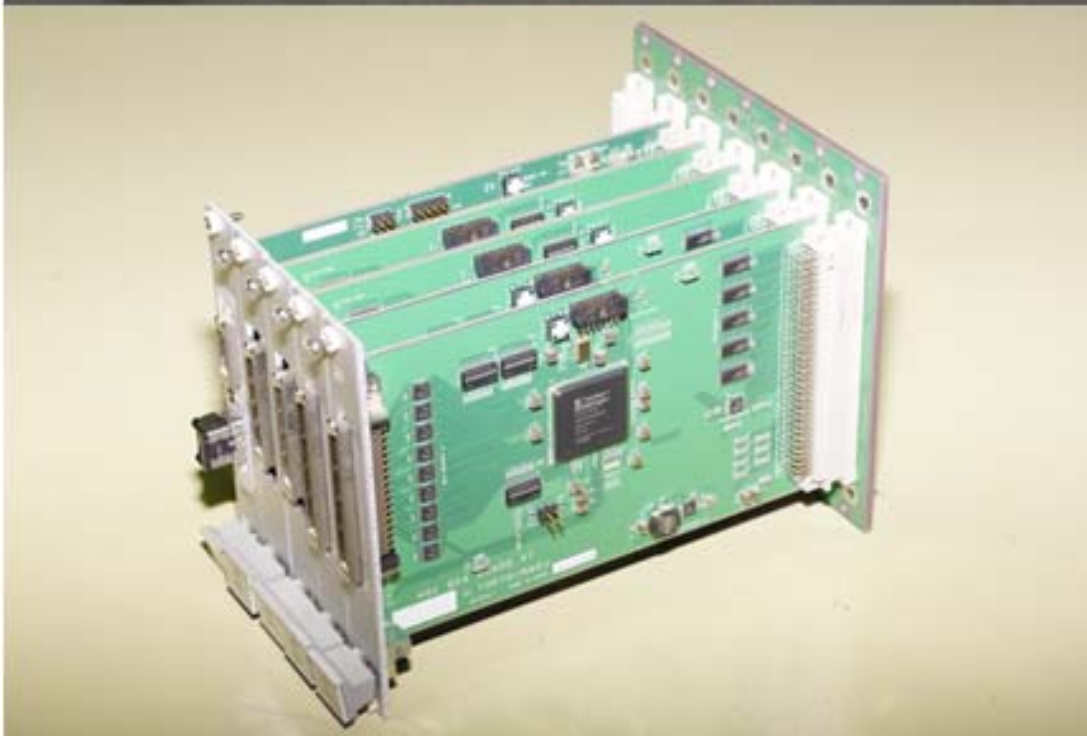
Readout time:  
 CCD Clocking ~ 15 sec  
 + transfer/save to RAID 13 sec

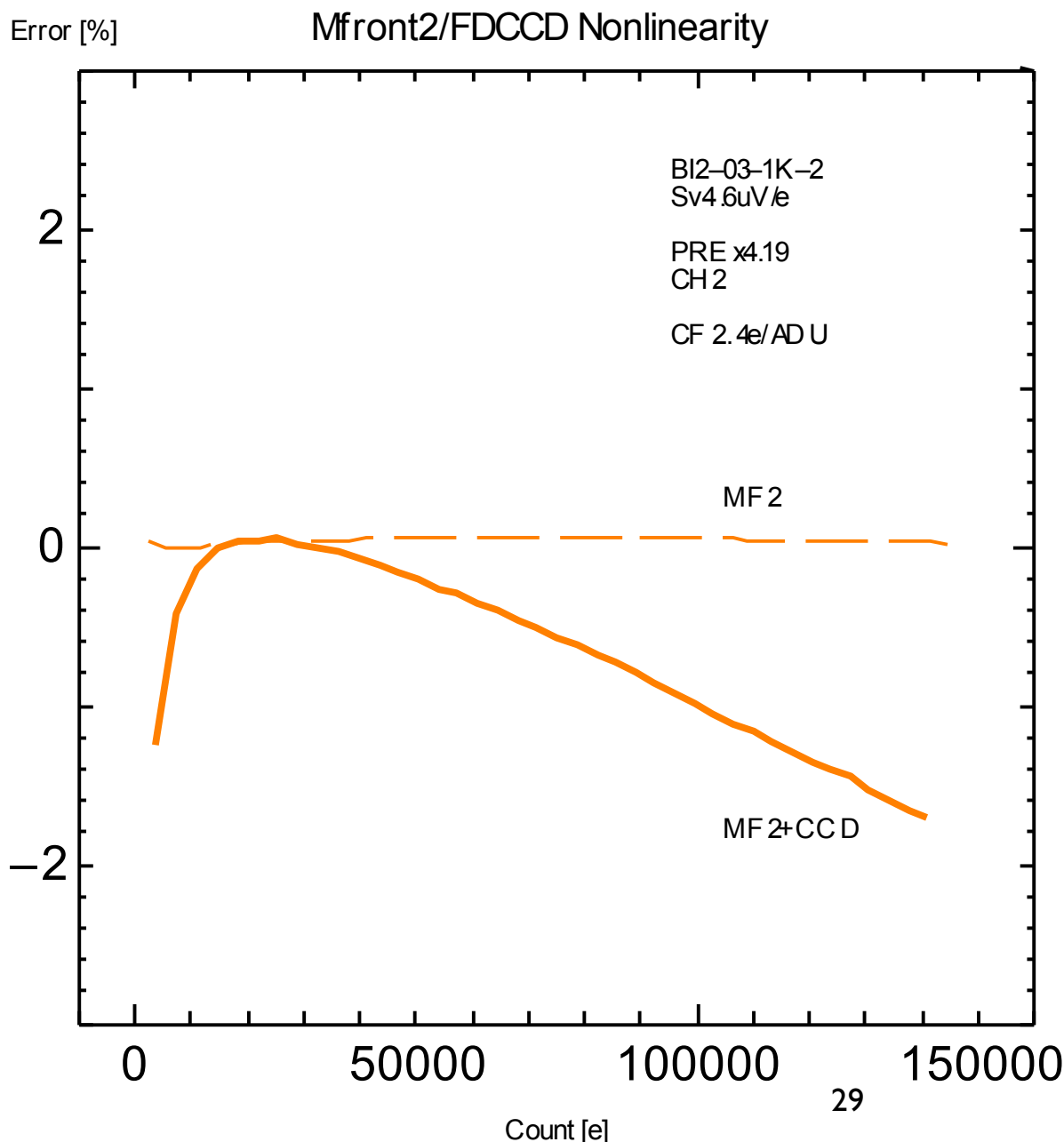


# HSC BEE



KEK  
NAOJ  
UT-Phys





Lab. measurement

Proto-type  
Electronics



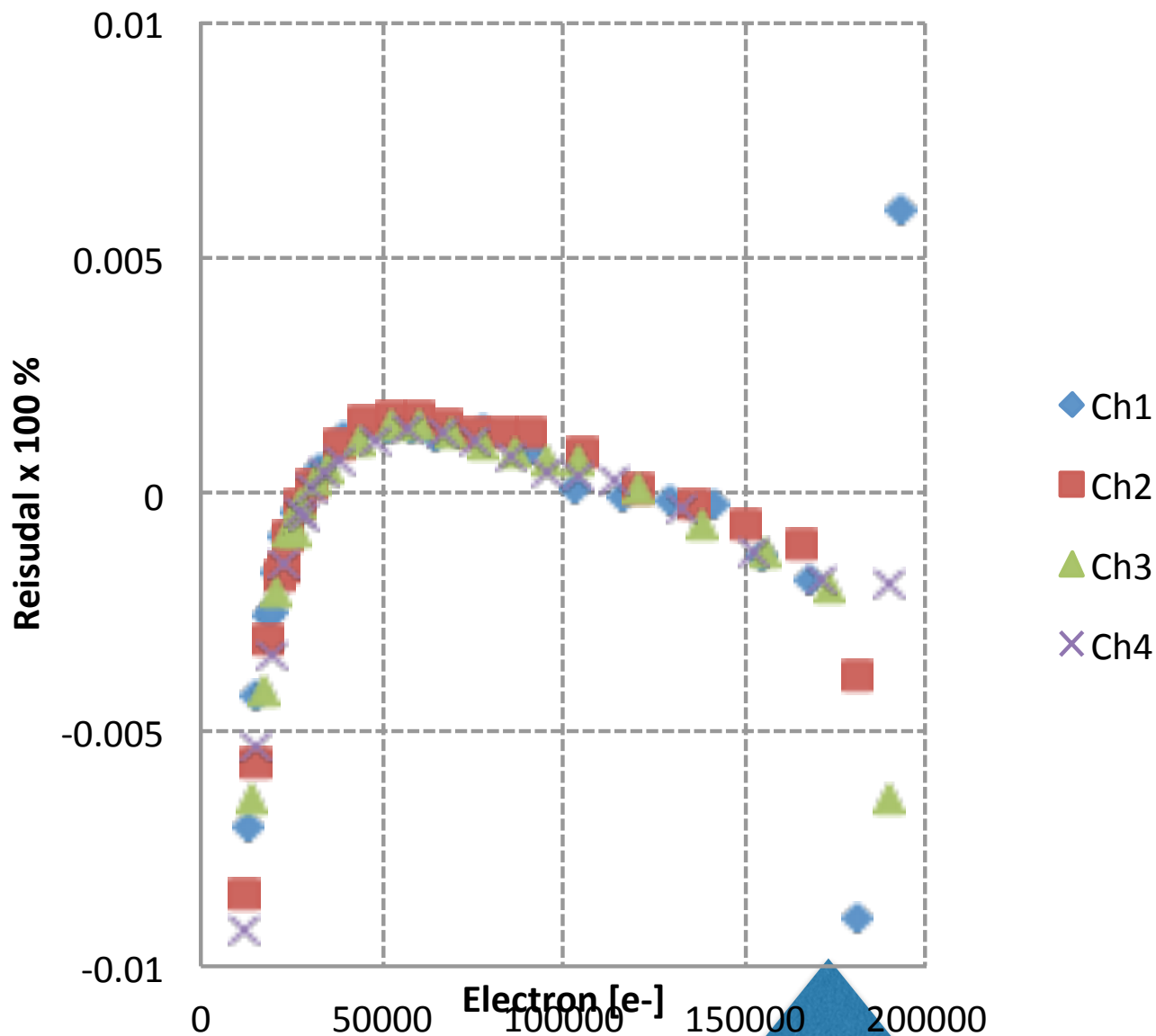


# Linearity

Lab. measurement

+0.5 %

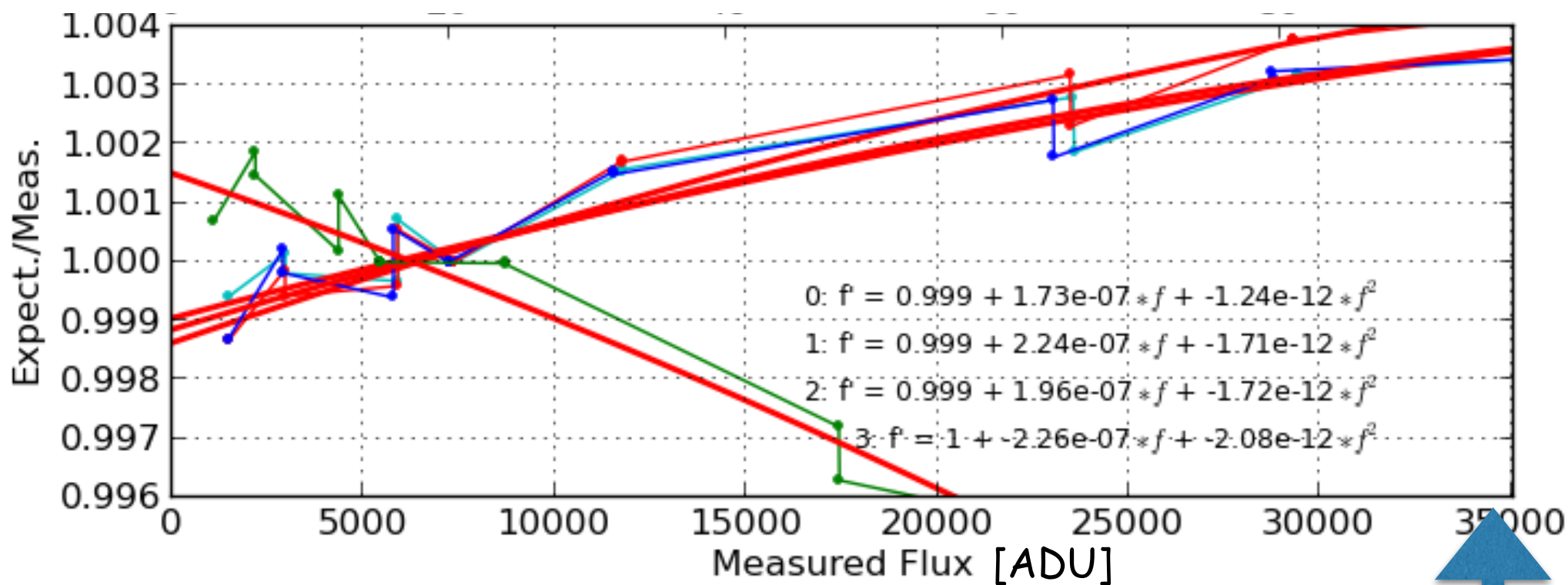
-0.5 %



HSC Electronics

# Linearity Measurement on Telescope

From flat images with different exposure T



somehow harsh results ...

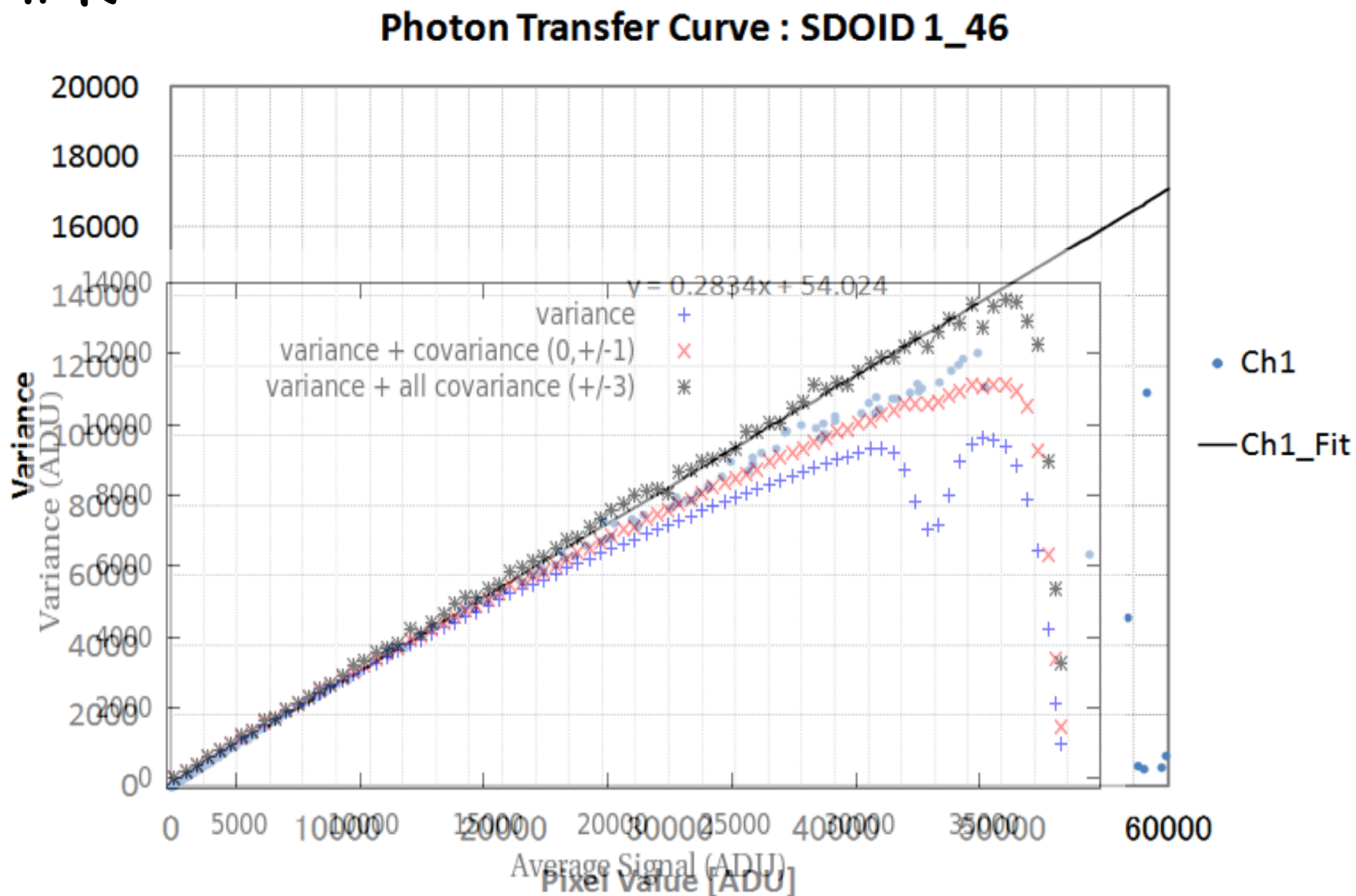
but P-V  $< \sim 0.5 \%$

$\sim 70 \%$  FW



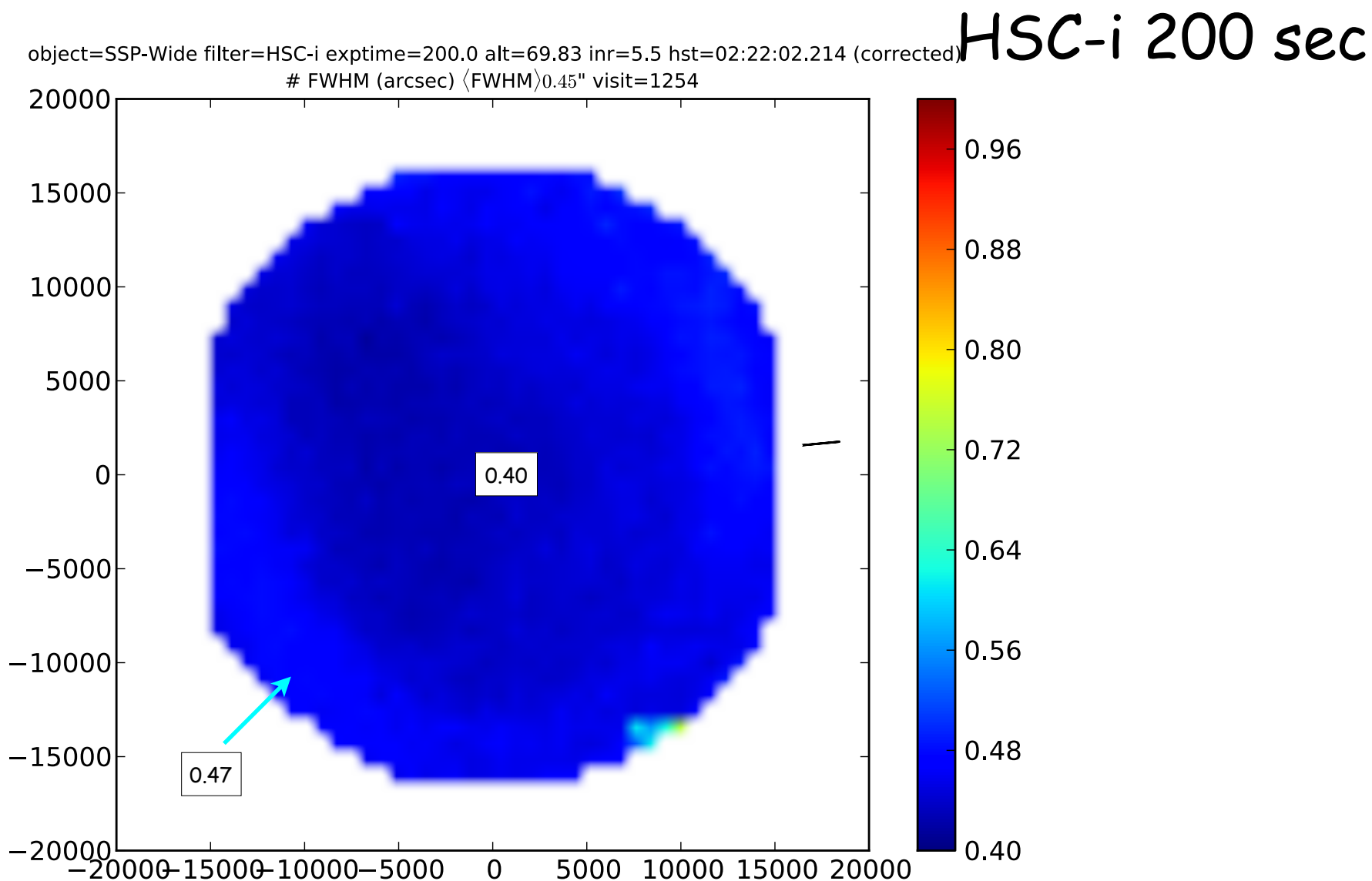
# Brighter Fatter Effect

HPK





# PSF Evaluation

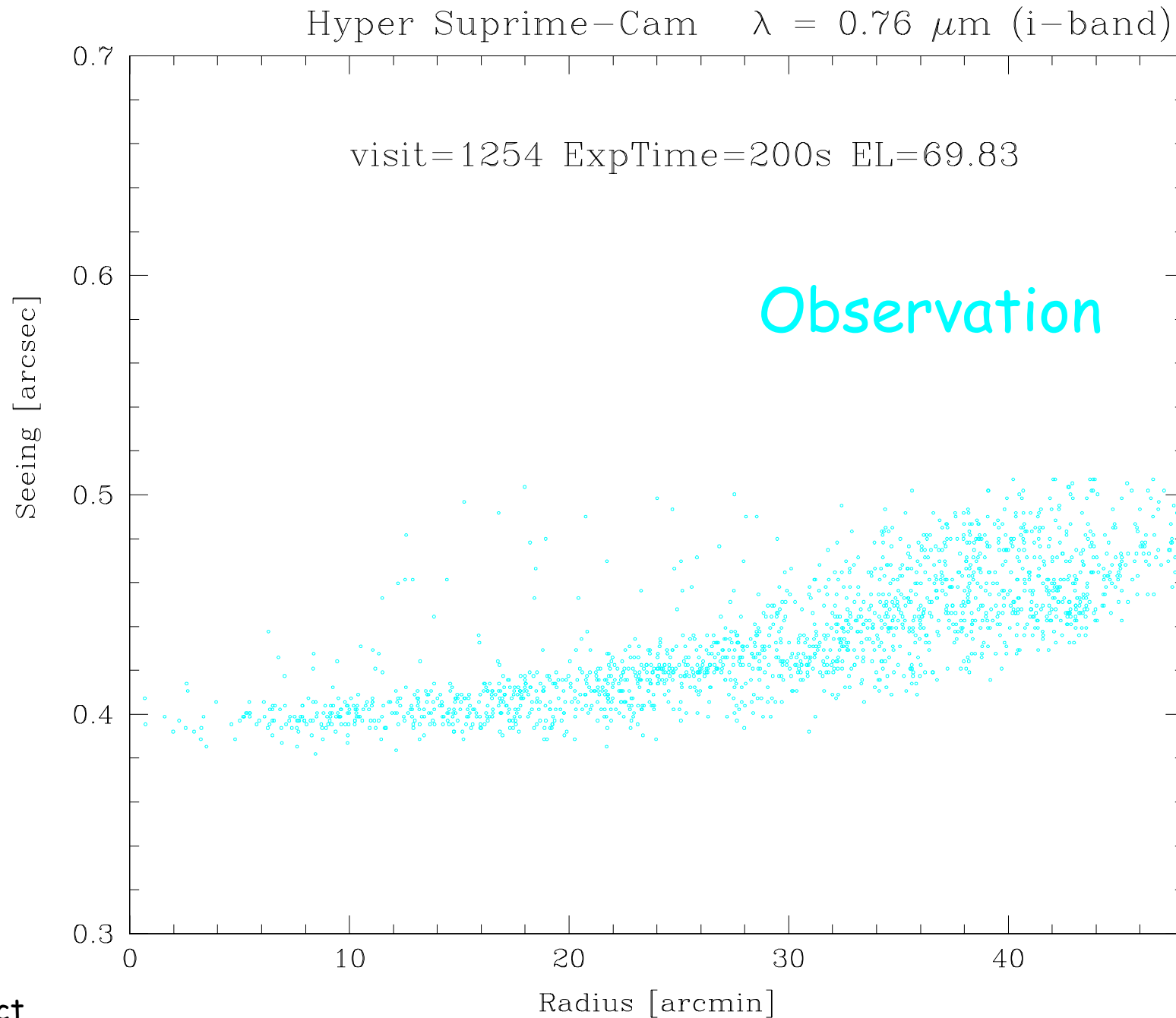


Very Sharp Image Realized as designed



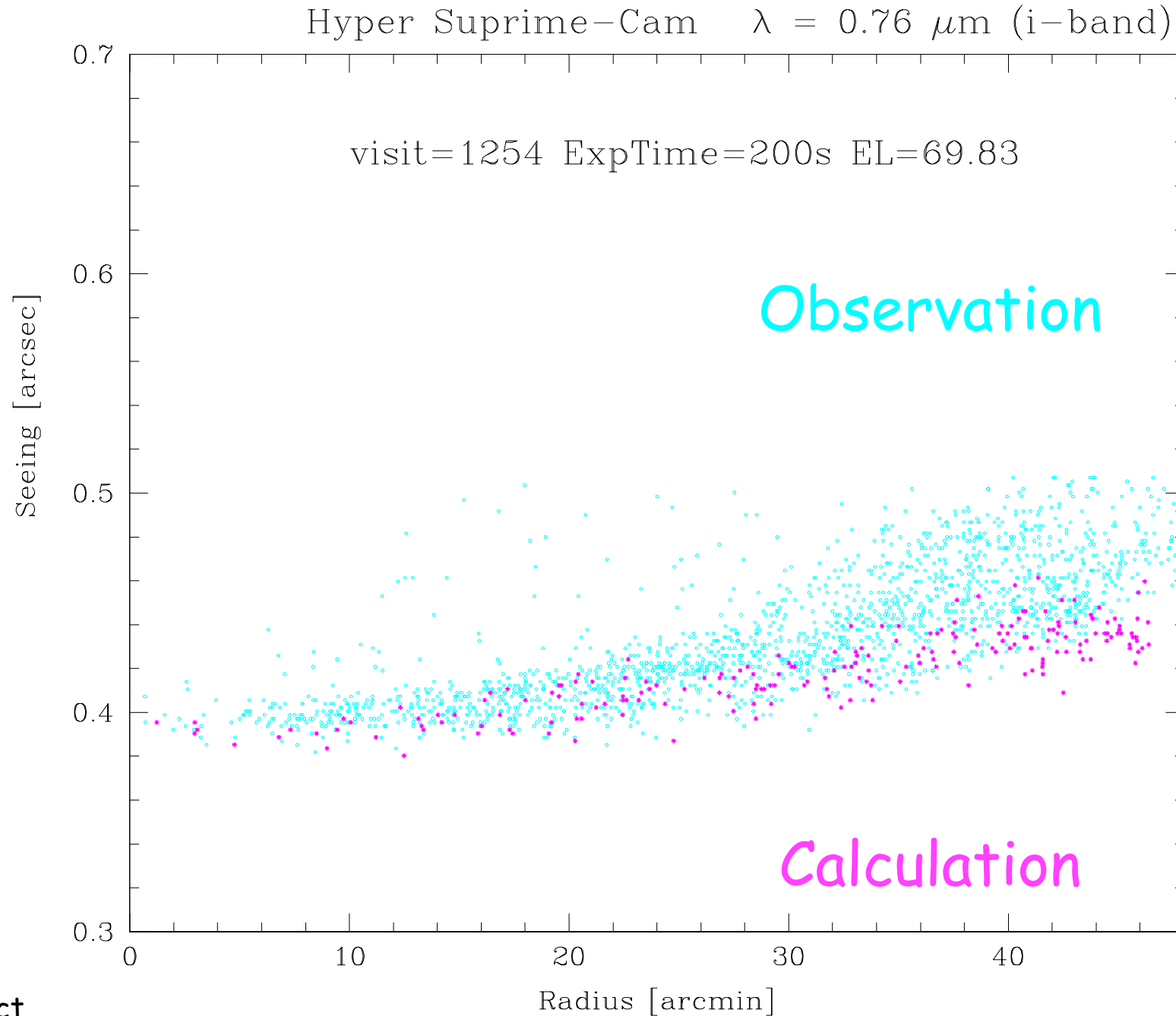


# PSF Evaluation





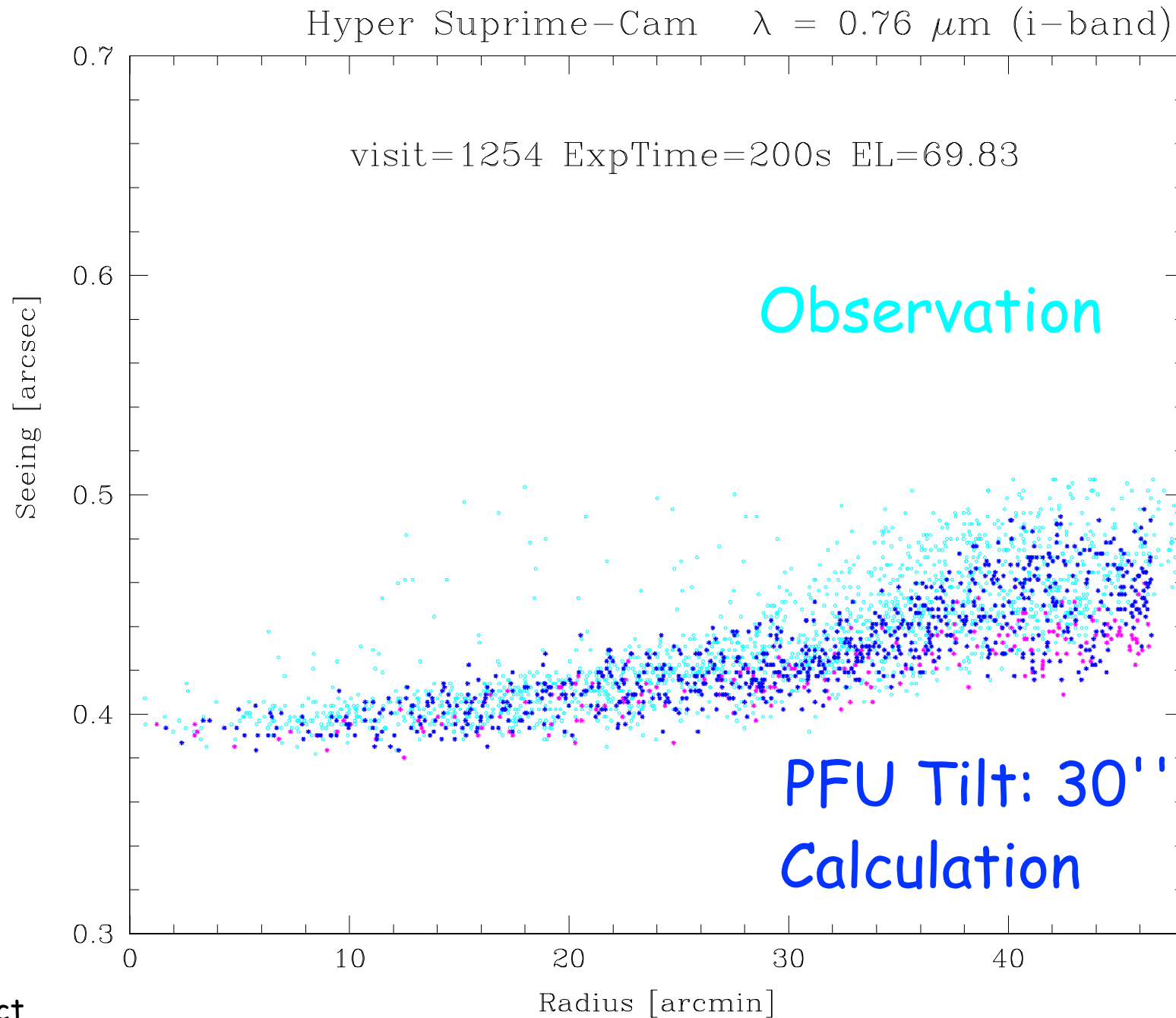
# PSF Evaluation





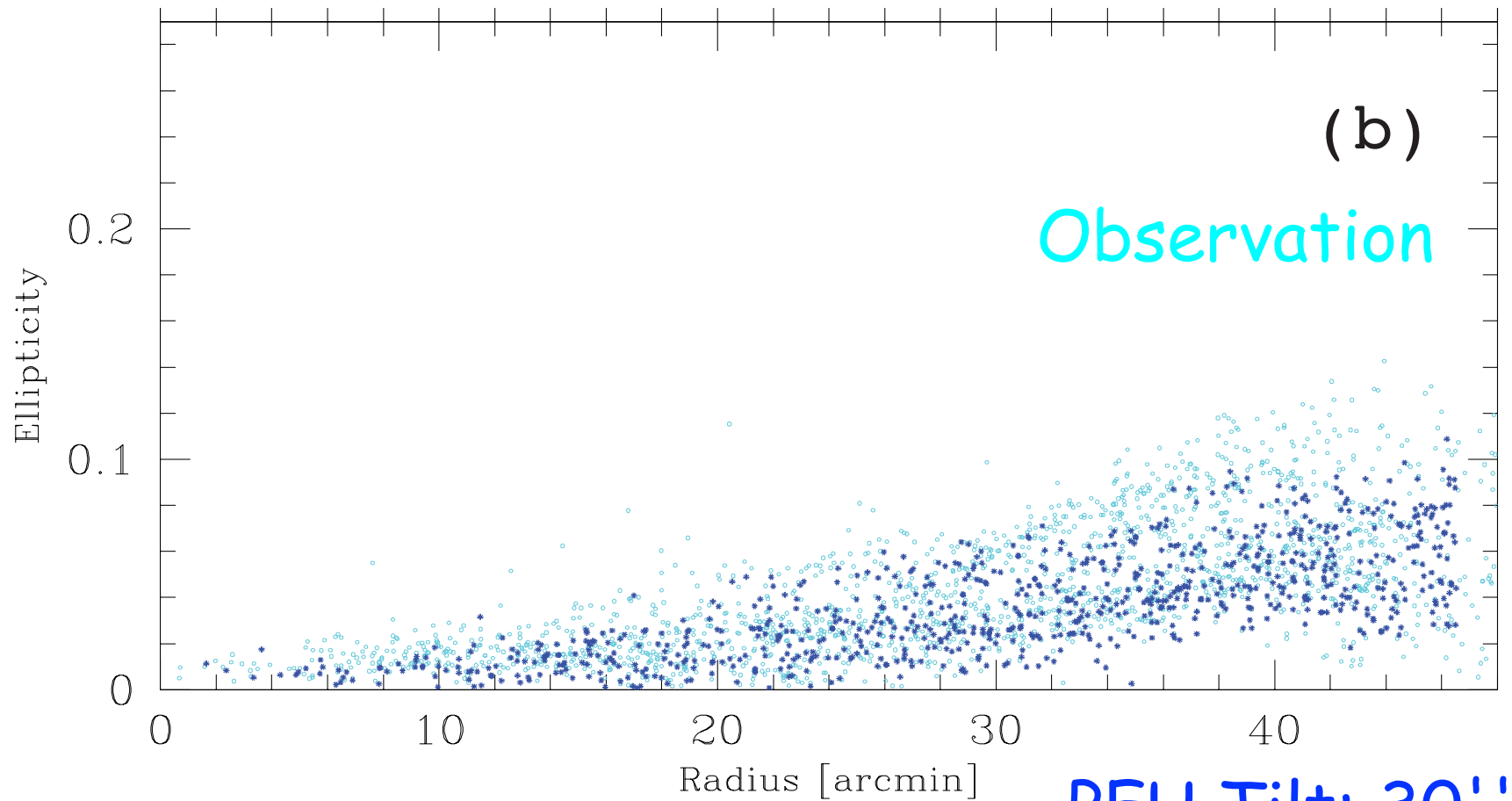


# PSF Evaluation



# PSF Evaluation

## Ellipticity



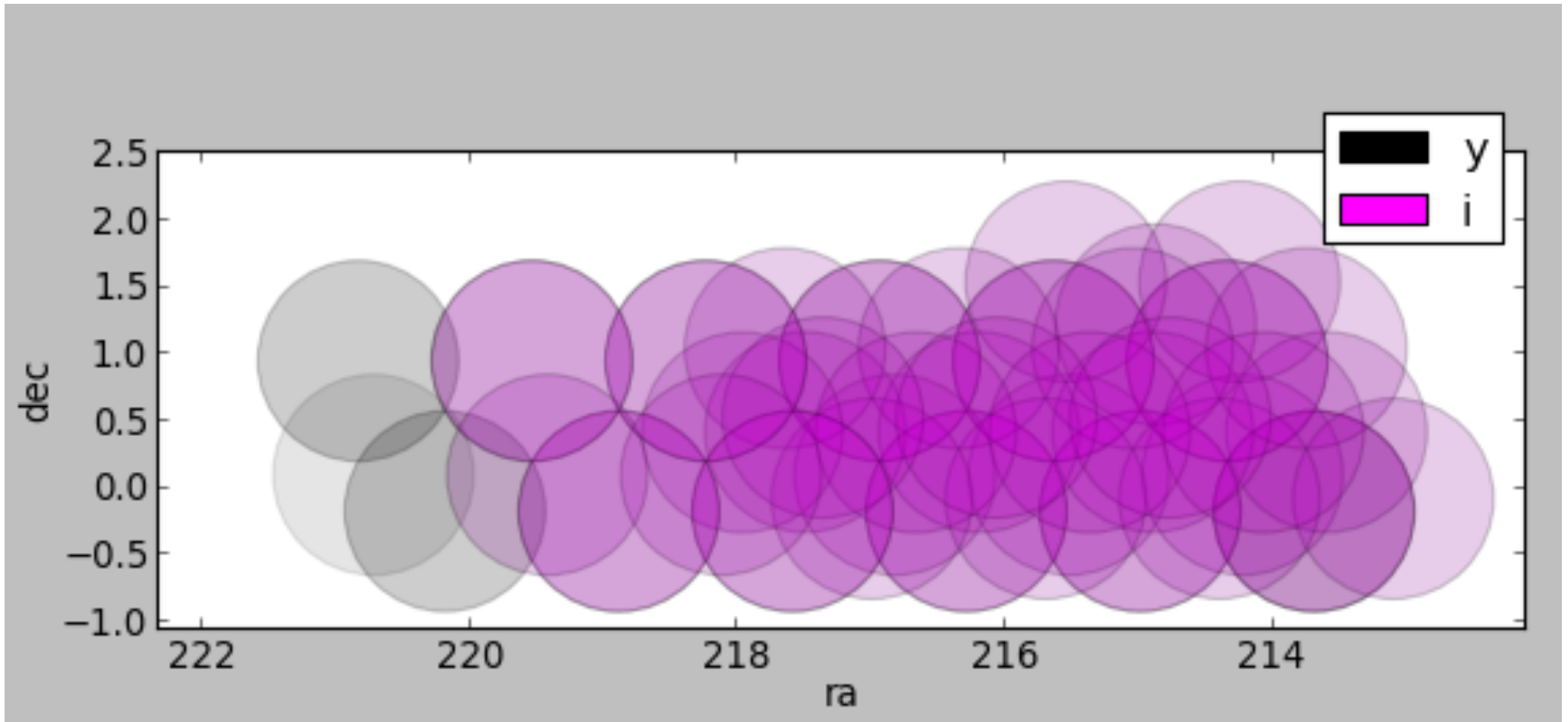
PFU Tilt: 30''  
Calculation





The survey began last February.

# Survey Mode Observation



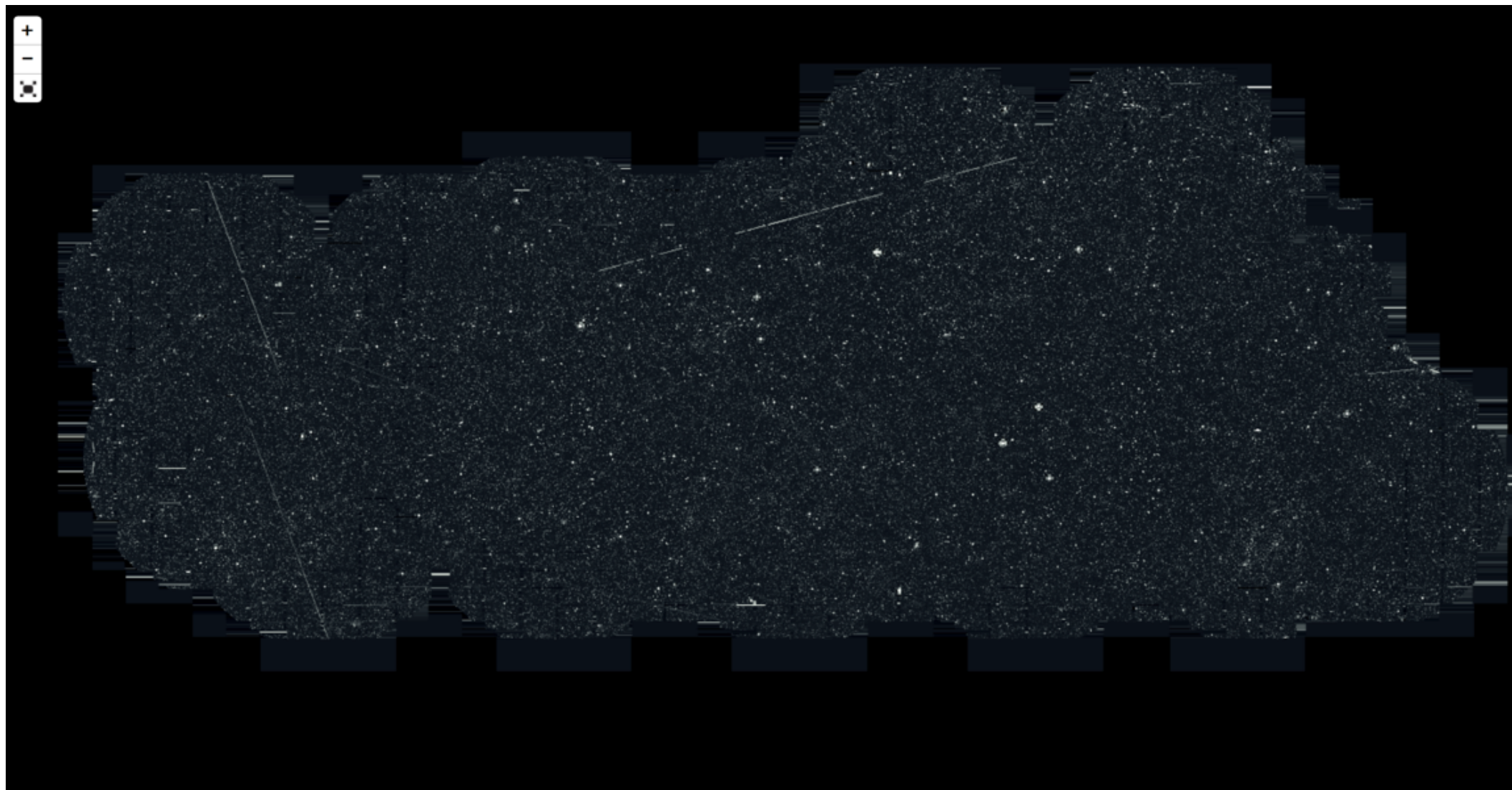
Step and Point multiple exposures

Example to cover  $\sim 20 \text{ deg}^2$



# GAMA Field

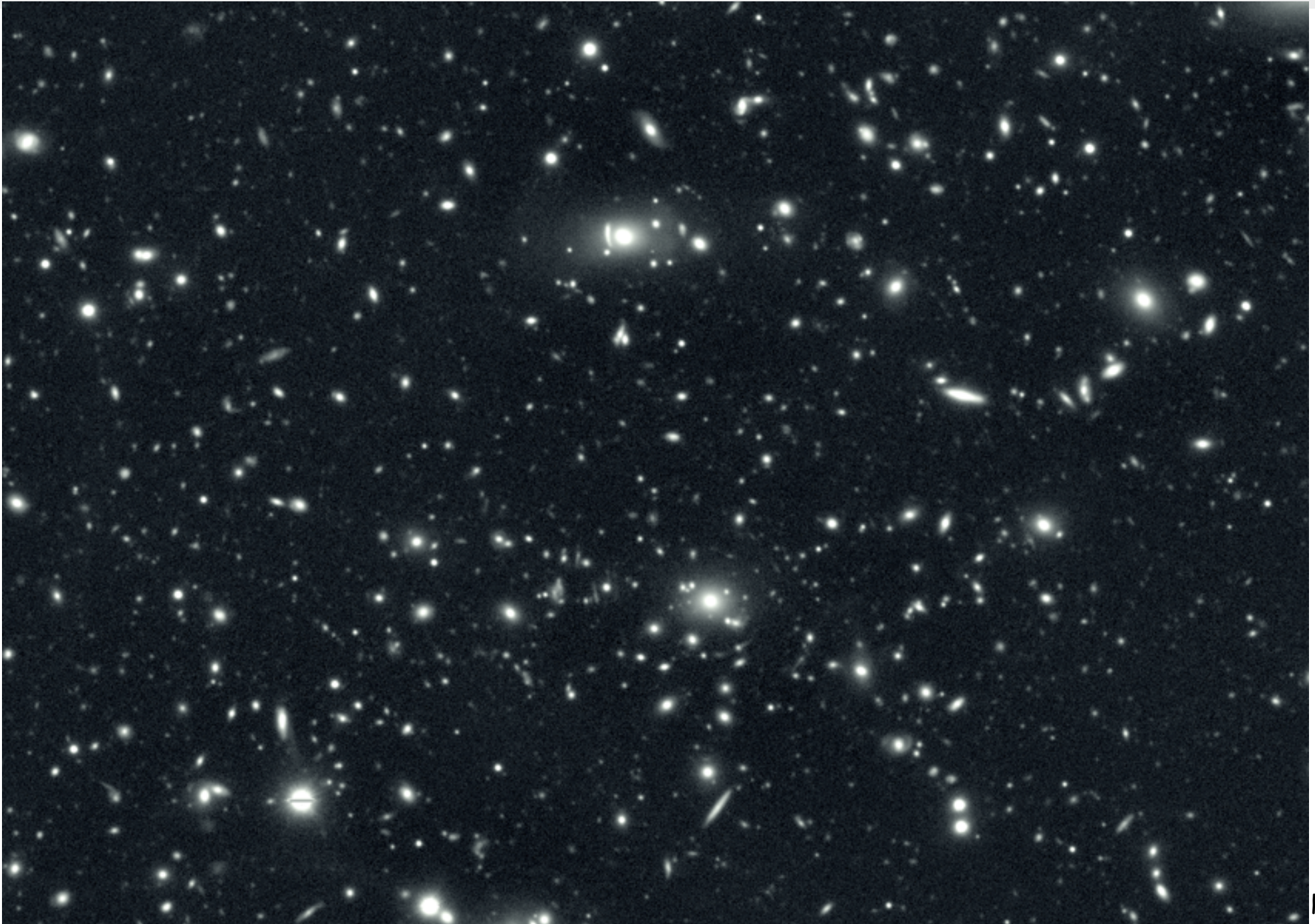
2014/3/27 2:20 - 5:20 am







# The Highest Peak on GAMA



# Conclusion

- HSC up and running
- Steady Operation since Feb 2014
  - Natural seeing limited imaging mostly
  - 30 sec dead time (inc. readout/save to disk/  
pointing change/guide star acquisition)
- Sufficient for most of observers
- But, need more understandings of our instruments to realize high precision measurements